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EFFECT OF
MOISTURE AND TEMPERATURE
OF CEMENT MORTAR SURFACES
ON QUALITY OF ADHESIVE BOND

An Investigation Conducted By

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Carbon fiber reinforced plastics (CFRPs) are receiving greater utilization in many structural applications due to their excellent mechanical and corrosion resistance characteristics. In addition, they can be designed and fabricated to get adequate strength and stiffness by changing the angle and the sequence of their laminations. The composite materials are increasingly used in industries of aerospace, automobile, ship, leisure and sports. Applications in strengthening existing reinforced concrete beams, piles, and decks using carbon fiber sheets are also being pursued. Carbon fiber sheets are utilized to strengthen waterfront concrete structures such as wharves and piers. The sheets are bonded to the underside of reinforced concrete pier using structural adhesives. Structural bonding implies the use of adhesives in an engineering application. A bonded joint should be capable of withstanding the stresses to be transmitted under different environmental conditions and over many years of service life. In this study three structural adhesives, i.e. epoxy resin systems, were chosen to establish adhesive bonds to the hydraulic cement mortar cubes. The assemblies were subjected to the combinations of three different temperatures and four different relative humidities in an environmental control chamber. Effects of moisture and temperature on the quality of bonds were investigated using pull-off tests. Results are reported describing different types of failures observed.

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EXECUTIVE SUMMARY

Carbon fiber reinforced plastics (CFRPs) are receiving greater utilization in many structural applications due to their excellent mechanical and corrosion resistance characteristics. In addition, they can be designed and fabricated to get adequate strength and stiffness by changing the angle and the sequence of their laminations. The composite materials are increasingly used in industries of aerospace, automobile, ship, leisure and sports. Applications in strengthening existing reinforced concrete beams, piles, and decks using carbon fiber sheets are also being pursued. Carbon fiber sheets are utilized to strengthen waterfront concrete structures such as wharves and piers. The sheets are bonded to the underside of reinforced concrete pier using structural adhesives. Structural bonding implies the use of adhesives in an engineering application. A bonded joint should be capable of withstanding the stresses to be transmitted under different environmental conditions and over many years of service life. In this study three structural adhesives, i.e. epoxy resin systems, were chosen to establish adhesive bonds to the hydraulic cement mortar cubes. The assemblies were subjected to the combinations of three different temperatures and four different relative humidities in an environmental control chamber. Effects of moisture and temperature on the quality of bonds were investigated using pull-off tests. Results are reported describing different types of failures observed.

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1. INTRODUCTION

Excellent mechanical and corrosion resistant characteristics have promoted the use of fiber reinforced plastics (FRP's) in many structural applications all over the world. Although the short-term mechanical properties of these materials are usually well documented, long-term durability issues still remain to be researched. The Naval Facilities Engineering Service Center (NFESC) is studying use of fiber reinforced plastics (FRP) to upgrade existing reinforced concrete piers and wharves. Carbon fiber reinforced plastic (CFRP) sheets are bonded to the under-side of reinforced concrete pier decks to increase their structural capacity, in particular to resist large patch loads from mobile crane outrigger floats. Laboratory tests of beam, slab, and pile scale models were conducted to quantify upgrades of moment capacity, shear strength, deflection, and ductility and to determine effects on failure modes. The composite plates and composite fabrics epoxy-bonded to the concrete structure for the purpose of external reinforcement showed great improvement in the performance of the host structure [1]. However, there is not enough information regarding environmental effects on the quality and durability of the bond between the reinforcement and the host structure.

2. ADHESIVE BONDS

At present two methods are used to reinforce the host concrete structure by using the carbon fiber reinforced plastics (CFRP). In one method the pre-impregnated plates are bonded to the concrete surface using a structural adhesive such as epoxy resins. In this case the structural adhesive may or may not be different from the polymeric matrix of the composite plate. In the second method, the dry fibrous reinforcement is impregnated with a resin system during placement itself. The composite is thus formed at the same time as it bonds to concrete. The resin thus serves the dual purpose of impregnating and bonding the fibers together, and bonding the composite to the concrete surface. This second method is therefore called a wet lay-up.

Structural bonding implies the use of adhesives in an engineering application. It is expected that the proposed bonded joint will be capable of withstanding the stresses to be transmitted. These stresses will be applied either in tension or shear, or in combination. The adhesive performance at various temperatures has also been studied using double lap joints. It was observed in the case of the adhesive Araldite that there is in general loss of room temperature strength for any gain in high temperature performance [2]. Many adhesive systems such as alkyd, epoxy ester, chlorinated rubber and styrene-butadiene paints showed loss of adhesion in 100% relative humidity (RH) conditions at room temperature. At lower RH values the loss of adhesion effect was less marked [3]. In case of epoxy adhesives it was observed in earlier research investigations that both with polar and non-polar surfaces the

properties of the adhesive joint are determined by an interaction of surface properties, adhesive properties and process variables. Porosity plays the significant role in case of porous materials like cement concrete or mortar. Flaws at the weak interfacial layer can cause poor adhesion [4]. The adhesive bond line thickness also affects the tensile strength. In general it was observed that the thicker the bond line, the lower the tensile strength [5]. The aspect ratio of the adhesive film is defined as the geometric ratio of its bonded area to force-free lateral surface area. Thin adhesive films have this ratio greater than 100. A thin adhesive film cannot contract laterally as a result of the geometric restriction. It has a lower Poisson's ratio than a thick film. The tensile bond strength depends on the aspect ratio [6].

3. SCOPE OF THE PRESENT STUDY

It is proposed to limit the present project to the study of the environmental effects (effects of different temperatures and humidities) on the quality of bonds to the hydraulic cement concrete or mortar surface. Out of many available resin systems such as unsaturated polyesters, vinylesters, phenolic resins and epoxies, only epoxies were chosen for the project. This is so because polyester resins are not very resistant to alkalies and are typically avoided for uses in concrete [7]. Vinylester resins are resistant to a wide range of acids as well as to chloride salts making them ideal for marine environments. However, the volume shrinkage of vinylester resins upon cure is significantly higher than for epoxy resins [8]. Phenolic resins have not been used to a wide extent in fiber reinforced composites. They are highly aromatic materials and have very short distances between crosslinkable points. Thus, their cured networks are relatively brittle. Moreover many of them have large volumes of volatiles upon cure [9]. On the other hand, epoxies have many desirable properties as structural adhesives. They cure with only a fraction of the shrinkage of vinyl-type adhesives such as polyesters and acrylics. Consequently, less strain is built into the bond line, and the bond is stronger. They exhibit low creep. The epoxies in the unmodified state cure without releasing water or other condensation byproducts. They are resistant to moisture. Moisture does not affect epoxy but will migrate through the joint and deteriorate the substrate.

Epoxy adhesives are particularly compatible with Portland cement concrete or mortar because of the insensitivity to the alkali and moisture contents of this structural material [10]. It was observed that when epoxy bonded joints are subjected to moisture or water immersion, the failures usually occur at the interface. This indicates the importance of proper surface preparation of the adherends. However, it opens the area of research where there is either no opportunity or limited opportunity to prepare the surface of one of the adherends, say, that of the concrete structure. It was therefore decided to undertake an investigation of the effects of dry and moisturized mortar surfaces on the quality of the adhesive bond. It was proposed to vary both temperature and moisture content of cement mortar cube surfaces by conditioning them in an environmental control chamber.

4. METHODS OF TESTING OF ADHESIVE BONDS

A wide range of approaches is available for estimating the strength of concrete or mortar. These include destructive methods such as cube or cylinder compression to failure testing, nondestructive methods and partially destructive tests. In the last category is included a test called the pull-off test developed originally by A. E. Long [11]. Figure 1 shows schematically the simple arrangement of the pull-off test. It involves bonding a circular steel or aluminum probe to the concrete surface using an epoxy resin adhesive which is stronger than concrete in tension. An increasing tensile load is applied to the disc by means of a portable hydraulic jack. Since the tensile strength of the epoxy resin is greater than that of the concrete, the latter will fail. From the peak load applied to pull off the disc from the concrete, a nominal (engineering) tensile strength of the surface is calculated dividing the force (load) by the area of the disc [12]. The ASTM Standard D4541-93 describes a similar partially destructive test called 'Pull-off test for Adhesion' [13]. It is designed not for the estimation of the tensile strength of the substrate but for the estimation of adhesive strength of a coating to the substrate. In this test an aluminum dolly in place of a steel disc is glued to a coating of the substrate. An instrument called Elcometer 106 Adhesion Tester is then used to pull off the glued dolly normal to the glued surface [14]. In the list of physical/chemical properties of coatings, the bond strength is typically referred to in terms such as 'greater than 200 psi' etc..

Figure 2 shows schematically different types of expected failures of an assembly. Failures are classified as either substrate, adhesive, cohesive or mixed. In the adhesive failure, the adhesive layer separates from the substrate. In the cohesive failure, the adhesive layer breaks into two portions, one remaining attached to the substrate (mortar cube in this case) and the other attached to the dolly. We expected higher number of substrate failures and negligible cases of cohesive failures in this work. In the case of a mixed failure, the percentages of the substrate and adhesive failures will be estimated by careful visual observation using a magnifying glass [15]. This new version of the original 'Pull-off Test' thus can be used for different purposes. It can be used to measure tensile strength of a cement concrete or mortar as in the original version, or the adhesion strength of a coating on a concrete surface, or the adhesive strength of the glue used to attach the aluminum dolly to the plain surface of a concrete. The test could also be used to study the effect of contaminated concrete surface on the adhesion of a coating to the surface [16]. Contaminants at the concrete surface affect osmotic pressure and adhesion. Different versions of the pull-off test are useful for in-situ testing of concrete specimens of big size. For small size specimens of cement concrete or mortar cubes of 2 inches in dimension, a tensile testing machine like Instron or MTS, could be used to get data more accurately than that could be read from the Elcometer instrument primarily designed for paint and coating testing.

5. EXPERIMENTAL SETUP

It was decided to use the "Pull-off Test" for the purpose of studying the effects of the moisture on the quality of adhesive bonds to cement mortar surfaces. The test specimens prepared were the assemblies of mortar cubes, epoxy resin and sand blasted aluminum dollies as shown in Figure 3. Three different temperatures (70°F, 85°F and 100°F) and four different relative humidities at each temperature (50% RH, 65% RH, 80% RH and 95% RH) were chosen for the study. About 108 mortar (Portland cement + sand + water) cubes of dimension 2 x 2 x 2 in were cast using plastic molds (impermeable formwork of polypropylene plastic material). The sand to cement ratio of the mortar was 3:1 and the water to cement ratio 0.5. The cubes were kept moist for 28 days. After that period they were kept in the laboratory at ambient temperature and humidity. On one of the smooth faces of each mortar cube an aluminum dolly was attached using the structural epoxy adhesive. A dolly resembles an hourglass in shape, about half an inch tall, and three quarter inch in diameter. Figure 3 shows the dimensions of the cement mortar specimens used in the experimental work.

The mortar cube surfaces were wire brushed and then dusted off with a soft brush making them free of laitance and contamination. The surface abrasion of the dollies helped establish the proper mechanical anchoring to the mortar surface through a thin film (less than 1/16 in thick) of an epoxy resin. It was decided to use three different epoxy resins - Sikadur 30, Sikadur 32 Hi-Mod, and Madewell 1312F to glue the aluminum dollies to the brushed surfaces of the cubes. All three epoxy resins are two-component systems. They were mixed and stirred according to specifications recommended by their manufacturers. These are listed in the Appendix. For each cube, two dollies were attached one on the surface coated with a thin layer of a primer and other on a surface without primer. The primer Sikadur 55 SLV was used with resins Sikadur 30 and 32. The primer Madewell 927 was used with the resin Madewell 1312F. Their specifications are also included in the Appendix. A primer works as a penetrant as well as sealer. It was expected to fill micropores in concrete or mortar and not air bubbles or blow holes. Only a thin layer (1 mil or 2 mils) of primer is supposed to perform its expected function. The thickness of a dolly and a cube pair were measured separately using vernier caliper. Their masses were also measured.

Dollies were mounted on the surfaces of the mortar cubes using thin layers of epoxy resins and were held in position for a couple of minutes with a constant pressure. Three samples for each epoxy system were prepared. So for a chosen pair of temperature and relativity humidity, 9 samples, three each for three epoxies, were prepared each carrying two dollies, one on a surface with primer and another on a surface without primer. For four different relative humidities at the same temperature, a total of 36 samples was conditioned. For three different temperatures, the total added to 108 samples. The tensile tests performed were similar to the ASTM Standard D4541-93-Pull-Off Strength of Coatings. Instead of using a portable Elcometer 106 Adhesion Tester, the pull-off tests were carried out by using a computerized Instron Testing Machine. A special fixture was prepared to align the mortar cube with a dolly along the vertical axis of the tensile loading machine so that the applied load

was normal to the cube surface. Misalignment was avoided because it can change a tensile test into a peel-off test.

Each set of 9 cubes was cured for 7 days in the environmental control chamber set at the chosen values of temperature and relative humidity. The procedure was repeated for 12 sets. After 7 days, assemblies were taken out of the chamber. The total thickness of each assembly was measured using the vernier caliper. By subtracting the individual thickness of the dolly and the cube from the thickness of the assembly, the thickness of the epoxy layer was computed. The excessive epoxy layers around the base of the attached dollies were removed using the testing apparatus sharp hollow cylindrical scraper before the pull-off tests. The assemblies were pulled off using the special fixture (Figure 4) attached to the Instron testing machine Model 4206. The elongation rate for all 216 tests was fixed at 0.01 inch per minute. A 1000 lb capacity load cell of was used. The load range of 500 lb (on the Y-axis) and the elongation range of 0.5 inch (on the X-axis) were set for all tests.

6. EXPERIMENTAL DATA

A computer equipped with a data acquisition system acquired load and elongation values during each test and plotted them on the screen. For each test, peak tensile load to pull-off the dolly was recorded. After the break of the assembly, the dolly with the pulled-off portion of substrate was weighed again to calculate only the detached mass of the substrate. The combined thickness of the dolly and the mortar chunk at the point of the deepest extent was measured to calculate the maximum depth of the mortar chunk. Viewing through the magnifying glass, the percentages of the mixed failures were estimated. Thus for each test, the mass of the mortar cube, the peak load to pull off the dolly, the adhesive film thickness, the pulled-off mass of mortar layer, maximum depth of the detached mortar layer and types of failures that occurred were recorded.

For the chosen pair of the temperature and relative humidity, six tests were run for each of three epoxy resins. This group of 18 tests is called Set #1. For three different temperatures and four different RH values, a total of 216 tests were performed grouped among twelve sets. In a given set, for each epoxy there were three tests for dollies attached to surfaces with no primer and another three to surfaces with primer. On each cube two dollies were attached, one on the surface as it was and the other on the surface carrying a thin coating of the primer. The twelve sets thus constituted the initial direct data from physical measurements and testing. Later on, the average peak load was calculated from three tests on the surfaces with no primer. The procedure was repeated for three tests on surfaces with primer. The data from twelve sets from 1 to 12 are presented in Tables 1 to 12.

The following abbreviations were used in the test names.

1) In Set #1, the nine tests are named N11 to N19. In Set #8, the tests were named N81 to N89 and so on. Thus the first test was N11 and the last was N129 in Set #12, adding to 108.

2) The suffix 'P' indicates a test on a surface with primer. These tests are named N11P to N19P. Thus the first test was N11P and the last was N129P in Set #12, adding to 108.

3) The tests in which the pulled-off mortar mass was found to be equal to, or greater than 1.5 grams are identified with the star (*) at the end of their names.

4) The tests in which the mounted dollies slid down from the original location but stayed glued on the surface are identified with the suffix 'SL".

5) When the dollies did not stick at all to the surface or were pulled off with a peak load less than 25 pounds, the suffix 'X' was attached to their test names. The value of zero was entered for the peak load. The peak load of such test was excluded from the average.

6) The suffix 'R" was attached to those tests which were repeated.

7. REGROUPING AND PLOTTING OF DATA

In order to study the performance of the three epoxy resins separately, at different combinations of temperatures and relative humidities, new tables were constructed for each one of them. Thus Table 13 describes the performance of the adhesive Sika 30 at a temperature of 70°F, and at different relative humidities. Table 14 does the same at 85°F and Table 15 at 100°F.

From Table 13, three new data tables were constructed. In Table 13A, tests with primer are separated from those without primer. In Table 13B, the average of three peak loads is calculated for a single relative humidity (RH%) value. The procedure is repeated for adhesive film thickness, pulled off mass of mortar layer, and its thickness. Masses of individual cubes were also entered into tables. Their averages were not performed since they carry no significance for this study. In Table 13C, only average values of peak loads were listed. Thus two average peak load values (one with primer and other without primer) corresponded to a single pair of temperature and relative humidity values. These are used in plotting of experimental data for the purpose of comparing performance of the three different epoxy systems.

The procedure was repeated for the adhesive Sika 32 in Table 16 (with 16A, 16B and 16C), Table 17 (with 17A, 17B, and 17C) and Table 18 (with 18A, 18B, and 18C). One more repetition is performed for the adhesive Madewell 1312F in Table 19 (with 19A, 19B, and 19C), Table20 (with 20A, 20B, and 20C), and Table 21 (with 21A, 21B, and 21C).

The regrouped data of the epoxy Sika 30 from Tables 13C, 14C and 15C were plotted in Figures 5, 6, and 7. The regrouped data of the epoxy Sika 32 from Tables 16C, 17C and 18C were plotted in Figures 8, 9, and 10. The regrouped data of the epoxy Madewell 1312F from Tables 19C, 20C, and 21C were plotted in Figures 11, 12 and 13.

Data on types of failures from the last columns of Set #1 to Set #12 were regrouped in Table 22 to study their distributions at different temperatures and relative humidities irrespective of the epoxy resins used. The regrouped data from Table 22 were plotted as three different bar graphs, one for each temperature, in Figure 14 for 70°F, in Figure 15 for 85°F and in Figure 16 for 100°F.

8. EXPERIMENTAL RESULTS

8.1. Adhesive Sika 30

Figures 5, 6 and 7 show the behavior of the adhesive Sika 30 at three different temperatures. On each plot, there are two curves of the average tensile peak loads (ATPL), one for no primer and the second for with primer. Each point is the average of three tests. Curves are drawn through four data points at four different relative humidities.

8.1.1. Without primer

The maximum ATPL is 254.83 lbs at 70°F and 50% RH. The minimum ATPL is 121.8 lbs at 85°F and 50% RH. In general, the ATPL have decreased in going from lower temperature to the higher temperature.

8.1.2. With primer

The maximum ATPL is 284.53 lbs at 70°F and 50% RH. The minimum ATPL is 129.16 lbs at 100°F and 50% RH. In general, the ATPL have decreased in going from lower temperature to the higher temperature.

Both the maximum and minimum ATPL have values higher in tests with primer than those in tests without primer. However the curve of ATPL with primer is not above the curve without primer at all temperatures and relative humidities as expected.

8.2. Adhesive Sika 32

Figures 8, 9, and 10 show behavior of the adhesive Sika 32 at three different temperatures. On each plot there are two curves of ATPL, one for tests with primer and the other for tests without primer. Each point is the average of three tests. Curves are drawn through four data points at four different relative humidities.

8.2.1. Without primer

The maximum ATPL is 381.4 lbs at 85°F and 80% RH. The minimum ATPL is 122.7 lbs at 100°F and 95% RH. In general, the ATPL have values higher at 85°F than those at the lower and the higher temperatures.

8.2.2. With primer

The maximum ATPL is 380.8 lbs at 70°F and 50% RH. The minimum ATPL is 222 lbs at 100°F and 95% RH. In general the ATPL have increased in going from the lower temperature to the higher temperature.

Both the maximum and minimum ATPL have values higher in tests with primer than those in tests without primer. The curve of ATPL with primer is most of the time at a higher load level than the curve without primer, as expected.

8.3. Adhesive Madewell 1312F

Figures 11, 12, and 13 show behavior of the adhesive Madewell 1312F at three different temperatures. Each plot shows two curves of ATPL, one for tests with primer and other for tests without primer. Each point is the average of three tests. Curves are drawn through four data points at four different relative humidities.

8.3.1. Without primer

The maximum ATPL is 360.7 lbs at 100°F and 50% RH. The minimum ATPL is 118.5 lbs at 100°F and 95% RH. In general, the ATPL have increased in going from the lower temperature to the higher temperature.

8.3.2. With primer

The maximum ATPL is 436.3 lbs at 100°F and 50% RH. The minimum ATPL is 235.6 lbs at 70°F and 65% RH. In general, the ATPL have increased in going from the lower temperature to the higher temperature.

Both the maximum and the minimum ATPL have values were higher in tests with primer than those in tests without primer. The curve of ATPL with primer is most of the time at a higher load level than the curve without primer, as expected.

8.4. The Range of Average Tensile Peak Loads

Among all three epoxy systems (resins with primers), the highest ATPL is 436.3 lbs for Madewell 1312F with primer at 100°F and 50% RH.

Among all three epoxy systems, the lowest ATPL is 118.5 lbs for Madewell1312F without primer at 100°F and 95% RH.

Table A: Maxima and Minima in ATPL for Three Epoxy Resin Systems

EPOXY RESIN	PRIMER	ATPL (LBS)	NATURE	TEMPERATURE (°F)	RH%
Sika30	No	254.8	Max	70	50
Sika30	Yes	284.5	Max	70	50
Sika30	No	121.8	Min	85	50
Sika30	Yes	129.2	Min	100	50
Sika32	No	381.4	Max	85	80
Sika32	Yes	380.8	Max	70	50
Sika32	No	122.7	Min	100	95
Sika32	Yes	222.0	Min	100	95
Madewell	No	360.7	Max	100	50
Madewell	Yes	436.3	Max(highest)	100	50
Madewell	No	118.5	Min(lowest)	100	95
Madewell	Yes	235.6	Min	70	65

Out of 6 maxima of ATPL, 5 occurred at 50% RH, only one occurred at 80% RH and none occurred at the highest value 95% of RH used in the tests. Out of 6 minima of ATPL, 3 occurred at 95% RH, 2 occurred at 50% RH and only 1 occurred at 65% RH.

For the effect of temperature on ATPL, 3 maxima occurred at 70°F, 2 occurred at 100°F and only 1 occurred at 85°F. In the case of ATPL minima, 4 occurred at 100°F, 1 occurred at 85°F and 1 occurred at 70°F.

The diameter of a dolly was 0.787 inch (20 mm) and its area was 0.487 square inch. The greatest ATPL of 436.3 pounds is equivalent to 896 psi. The lowest ATPL of 118.5 pounds is equivalent to 243 psi.

The compression tests were run on three mortar cubes from the same stock from which 108 cubes were taken for the project. The average compressive strength was found to be 5000 psi. At this point it was found necessary to investigate the number of types of failures at

different combinations of temperatures and relative humidities. This data is presented in Table 22.

8.5. Types of Failures

In the assembly of the layered structure of aluminum dolly, adhesive film and the substrate of the hydraulic cement mortar cube, the weakest link was expected to be the substrate. Not in a single case was there any separation between the aluminum dolly and the adhesive used.

Out of 216 tensile pull-off tests, the 100% substrate failures occurred in 127 tests, equivalent to 59 percent. The 100% substrate failure means that the whole area of the pulled off dolly was covered with substrate. In the case of 80% substrate failures, the remainder 20% would be adhesive failure or interface separation.

In addition:
- between 99% to 80% substrate failures occurred in 50 tests equivalent to 23 percent;
- between 79% to 60% substrate failures occurred in 13 tests equivalent to 6 percent;
- between 59% to 1% substrate failures occurred in 22 tests equivalent to 10 percent;
- one hundred percent adhesive failures occurred in 3 tests equivalent to 1.4 percent;
- only one cohesive failure occurred equivalent to 0.5 percent.

The highest number (18) of 100% substrate failures occurred at 70°F and 50% RH. The lowest number (3) of 100% substrate failures occurred at 100°F and 95% RH.

For all epoxy resin systems used and at all RH settings the highest number (51) of 100% substrate failures occurred at 70°F. That number was followed by the smaller number (44) at the increased temperature of 85°F, and finally by the smallest number (32) at the highest temperature of 100°F. The data from Table 22 was plotted separately in Figures 14, 15, and 16 as three bar graphs for three different temperatures.

8.6. Strong Bonds

In certain tests, although the type of failure was 100% substrate, the mass of detached substrate was a thin layer attached to the adhesive film below. In a few other tests, big chunks of substrate were pulled off by the dolly. The tests with the pulled-off mass of substrate greater than or equal to 1.5 grams were identified by the star (*) sign in Tables 1 through 12. They are identified as strong bonds. The 35 strong tests are listed below.

Table B: Tests with Detached Substrate Mass Equal to or Greater than 1.5 grams.

TEST	RESIN	PRIMER	PEAK LOAD (LBS)	MORTAR MASS (GR)	TEMP (°F)	RH (%)	TYPE OF FAILURE
N13	Sika30	No	275.2	2.639	70	50	100%S
N12P	Sika30	Yes	297.7	2.595	70	50	100%S
N13P	Sika30	Yes	332.9	3.087	70	50	100%S
N16	Sika32	No	452.6	3.530	70	50	100%S
N14P	Sika32	Yes	390.9	2.727	70	50	100%S
N18	MW	No	315.2	1.746	70	50	100%S
N18P	MW	Yes	329.4	2.097	70	50	100%S
N21P	Sika30	Yes	235	1.882	70	65	100%S
N26P	Sika32	Yes	436	1.814	70	65	100%S
N28P	MW	Yes	167.3	1.85	70	65	100%S
N29P	MW	Yes	233.6	2.103	70	65	100%S
N45	Sika32	No	242.5	1.887	70	95	100%S
N46	Sika32	No	200.7	1.998	70	95	100%S
N48P	MW	Yes	369	1.924	70	95	100%S
N55P	Sika32	Yes	252.8	1.686	85	50	100%S
N56P	Sika32	Yes	483.8	1.677	85	50	100%S
N61	Sika30	No	237.6	1.686	85	65	100%S
N66	Sika32	No	281.3	2.027	85	65	100%S
N65P	Sika32	Yes	303.2	1.697	85	65	98%S
N67	MW	No	277.9	2.105	85	65	100%S
N67P	MW	Yes	256	1.731	85	65	100%S
N75	Sika32	No	340.1	3.947	85	80	100%S
N75P	Sika32	Yes	439.2	2.135	85	80	95%S
N76P	Sika32	Yes	373.7	2.640	85	80	100%S
N78	MW	No	320.8	1.557	85	80	100%S
N84P	Sika32	Yes	318	2.227	85	95	100%S
N85P	Sika32	Yes	280.9	1.514	85	95	100%S
N86P	Sika32	Yes	270.6	1.697	85	95	100%S
N89P	MW	Yes	370.6	2.720	85	95	100%S
N94	Sika32	No	322.5	1.715	100	50	100%S
N95P	Sika32	Yes	319.5	2.075	100	50	100%S
N105	Sika32	No	276.9	3.110	100	65	100%S
N108	MW	No	320.4	1.565	100	65	100%S
N121	Sika30	No	176.5	1.628	100	95	100%S
N127P	MW	Yes	209	1.608	100	95	100%S

Out of 35 strong tests, 6 tests belonged to Sika 30, 18 belonged to Sika 32 and 11 belonged to Madewell 1312F. Tests with primer were 21, and without primer 14. The distribution at different temperatures was 15 tests at 85°F, 14 at 70°F and only 6 at 100°F. The distribution at different relative humidities was 11 tests each at 50% and 65% RH, 4 tests at 80% RH and 9 tests at 95% RH.

8.7.   Weak Bonds

The peak pull-off load was less than 25 lbs in 6 tests out of 216 tests. The samples with improper adhesion, either due to the experimental error or due to other causes, were only 2.8 percent of the whole set. These were excluded from the average of the peak pull-off load. Out of 6 tests, 3 tests were on surfaces without primer and other 3 were on surfaces with primers. They are listed below.

Table C: List of Tests with Peak Pull-Off Load less than 25 lbs.

TEST	ADHESIVE	PRIMER	TEMPERATURE (°F)	RH (%)
N51	Sika30	No	85	50
N123	Sika30	No	100	95
N127	Madewell1312F	No	100	95
N32P	Sika30	Yes	70	80
N57P	Madewell1312F	Yes	85	50
N124P	Sika32	Yes	100	95

All three epoxies are involved. All three temperatures are involved. In the three cases with primers on the surfaces, thicker coats could be the cause of improper adhesion. In the three cases with RH 95% at 100°F, the moist surfaces could be cause of improper adhesion. Since they were excluded in calculating the average peak loads, their influence on the tests results is nil.

8.8.   Effects of Adhesive Bond Thickness on Pull-Off Strength

Attention was given to apply a thin uniform layer of the adhesive to the sand blasted surfaces of the dollies first, and then set them on the mortar surfaces with primer and without primer in pre-selected positions. They were held in positions by moderate pressure. All three

adhesives were in liquid paste form and hence got squeezed out from under the dollies. There was no control, therefore, on the thickness of the adhesive film between the dolly and the mortar surface. The adhesive film thickness were computed and are documented in Tables 1 to 12. It was observed that the resin Sika 30 formed films thicker than Sika 32 that in turn formed films thicker than Madewell 1312F. But the adhesive film thickness was also affected by the microscopic variations in the morphology of the individual mortar surfaces. No efforts, therefore, were made to establish the relationship between adhesive film thickness and the pull-off strength, although it was observed that the thicker films lead to the lower values of pull-off strengths in tests that could be reasonably compared with each other.

9. DISCUSSION OF RESULTS

Nine figures, from Figure 5 to Figure 13, are the plots of average tensile peak load (ATPL) versus relative humidity (RH) at 3 different temperatures for 3 epoxy resin systems. Among the resin systems, the curves of Sika 32 show ATPL, in general, at values higher than those of Sika 30, as expected. Between Sika 32 and Sika 30, the general trend can be explained by the difference in properties, as described by the manufacturer. The 7day cure tensile strength (ASTM D-638) of Sika 30 is 3600 psi, while that of Sika 32 is 5100 psi. Thus performance of Sika 32 was expected to be better than that of Sika 30. It was observed accordingly in this work. The data on the 7-day cure tensile strength of Madewell 1312F was not available.

The nine plots of Figures 5 to 13 show the improvement in the values of ATPL with the application of primer. It is interesting to note that the effect of primer becomes more dominant at higher temperatures for all resin systems, at all relative humidities. Primers may prevent outgasing from the substrate at higher temperatures, and thus improve the performance of the adhesive bond.

The bar graphs of Figures 14, 15, and 16 show trends in substrate and adhesive failures. The number of substrate failures decreased and that of adhesive failures increased in the environment of higher temperatures and relative humidities.

Among the strong tests, the number of those with primer is 1.5 times the number of those without primer. The number of strong tests decreased in the environment of higher temperatures and relative humidities.

Although the general trends observed in the averaged experimental data are consistent with properties of adhesives described by their respective manufacturers, deviations from the general trends were also observed in the individual data points. This may be due to certain

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chemical reactions (such as cross-linking) being accelerated at higher temperatures and certain other reactions being prevented from happening at a high relative humidity environment.

10. CONCLUSIONS

The total number of 100% adhesive failures was only 3 out of 216 tests. Out of 3, two occurred at 100°F and 95% RH, only one occurred at 85°F and 50% RH and none occurred at 70°F. Thus only 1.4% bonds turned out to be bad bonds.

It can be concluded, therefore, that all three epoxy resin systems performed their intended function of establishing a bond to the hydraulic cement mortar surfaces in the temperature range of 70°F to 100°F and in the RH% of 50 to 95. This happened 213 times out of 216, which is equivalent to 98.6% of the time.

The total number of mix failures (1% adhesive to 99% adhesive or equivalently 99% substrate to 1% substrate) was 85 out of 216 tests equivalent to 39 percent. It can be said therefore, that in 39% cases, bonds varied from good to fair to weak. The cases of 6 weak bonds are included in the mix failure category because they pulled out some substrate, albeit a small piece.

The total number of 100% substrate failures (better bonds) was 127 out of 216 equivalent to 59%. These cases do not tell us about the state of the bond unless we compare them on the basis of the quantity of mortar they pulled off. Out of these are selected 35 tests that pulled a mortar mass greater than 1.5 grams. These are the best bonds. The adhesive bond performance is summarized in the Table D.

Table D: Summary of Quality of Bonds

SERIAL NO.	BOND QUALITY	QUANTITY
1	Best	35
2	Good	92
3	Fair to weak	85
4	No bond	3
5	Cohesive failure	1
Total		216

11. RECOMMENDATIONS

In the research work reported here, there was no way to know the condition of the adhesive film formed under the dolly in contact with the mortar cube surface before subjecting it to a destructive test like the pull-off test. Sometimes a kissing bond is formed with intermittent contact with the substrate rather than a uniform bond. Sometimes the film becomes thicker on the edges. These non-uniformities in thickness and contact as well as gaps in the adhesive film can be detected prior to destructive testing by means of nondestructive techniques such as ultrasonics. This process will bring control on the formation of adhesive films. It will lead to the understanding of their true performance without being colored by the effects of the film defects.

12. ACKNOWLEDGMENTS

13. REFERENCES

1) Malvar, L. J., Warren, G. E. and Inaba, C. M., "Composite Applications in the Navy Waterfront Infrastructure," Special Publication SP-2018-SHR, Naval Facilities Engineering Service Center, Port Hueneme, CA 93043-4370.

2) Gallant, P. E. and Swaffer, C. S., "The assessment of Structural Bonds by Destructive Methods," Aspects of Adhesion, Proceedings of the Conference held at the City University, London on 5-6 April 1967 and 9-10 April 1968, CRC Press, 1969, pp.51-75.

3) MacDonald, N. C., "The Effect of Moisture on Adhesive Bonds, Aspects of Adhesion, CRC Press, 1969, pp.123-141.

4) Garnish, E. W. and Haskins, C. G., "The Effect of Surface Conditions when Bonding with Epoxy Adhesives," Aspects of Adhesion, CRC Press, 1969, PP.259-276.

5) Torres, F. C.,"A Study to Determine the Optimum Bond Line Thickness of Two Epoxy Resin Formulations," University of Arizona Engineering Research Laboratories Report, January 1966.

6) Masuoka, Mineo and Nakao, Kazumune, "Effect of Aspect Ratio on Tensile bond Strength for Butt Joint of Internal Fracture-Theoretical and Experimental Analysis," Adhesion Measurement of Thin Films, Thick Films, and Bulk Coatings, Editor: K.L. Mittal, ASTM STP 640, pp.342-361.

7) Malvar, L. J., "Literature Review of Durability of Composites in Reinforced Concrete," Special Publication, SP-2008-SHR, Naval Facilities Engineering Service Center, Port Hueneme, CA 93043-4370.

8) Riffle, J. S., Lesko J. J. and Puckett, P.M., "Chemistry of Polymer Resins for Infrastructure," Fiber Composites in Infrastructure, Proceedings of the Second International Conference on Composites in Infrastructure, volume I, ICCI '98, Tucson, Arizona, USA, Editors: H. Saadatmanesh and M.R. Ehsani, 5-7 January 1998, pp. 23-34.

9) Introduction to Composites, SPI Composites Institute, 1992, p.14

10) Shimp, D. A., "Epoxy Adhesive," Epoxy Resin Technology, Editor: Paul F. Bruins, Interscience Publishers, 1968, pp.159-183.

11) Long, A. E. and Murray, A. McC., "The 'Pull-off' Partially Destructive Test for Concrete," In Situ Nondestructive Testing of Concrete, Editor: V. M. Malhotra, ACI publication SP-82, Detroit, 1984, pp. 327-350.

12) Basheer, P. A. M., McCauley, A. and Long, A. E., "Influence of Moisture Condition of Concrete on the Performance of Surface Treatments, Durability of Concrete, Proceedings of Fourth CANMET/ACI International Conference Sydney, Australia, 1997, Editor: V. M. Malhotra, Volume 2, SP-170, pp.1049-1072.

13) Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers, ASTM D4541-93, Volume 06.02, 1994 Annual Books of ASTM Standards, pp. 344-347.

14) Protective Coatings Inspection Equipment, S. G. Piney & Associates, Inc., P.O. Box 9220, Port St. Lucie, Florida, p. 29.

15) Gaughen, C. David, "Inspection/Assessment of Hydraulic Maintenance Shop Concrete Floor Coating containing 3% Asbestos Fibers at Nas Lemoore," Site Specific Report, SSR-2218-SHR, May 1996, Naval Facilities Engineering Service Center, Port Hueneme, CA 93043-4370.

16) Gelfant, Frederick S., "Contaminated Concrete-Effect of Surface Preparation Methods on Coating Performance," Journal of Protective Coatings & Linings, Volume 12, Number 12, December 1995, pp.60-72.

Table 1. Set #1 – Temperature 70°F, Relative Humidity 50%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
			Adhesive Sika 30 without Primer			
N11	280.312	168.3	0.012	0.573	0.058	100%S
N12	279.058	321	0.008	0.716	0.104	100%S
N13*	275.824	275.2	0.012	2.639	0.199	100%S
			Adhesive Sika 30 with Primer Sika 55			
N11P	280.312	223	0.020	0.594	0.077	100%S
N12P*	279.058	297.7	0.010	2.595	0.179	100%S
N13P*	275.824	332.9	0.007	3.087	0.213	100%S
			Adhesive Sika 32 without Primer			
N14	270.399	372.1	0.002	1.008	0.084	100%S
N15	282.337	278.1	0.002	1.379	0.151	100%S
N16*	291.342	452.6	0.004	3.530	0.192	100%S
			Adhesive Sika 32 with Primer Sika 55			
N14P*	270.399	390.9	0.001	2.727	0.194	100%S
N15P	282.337	340.3	0.002	0.532	0.06	100%S
N16P	291.342	411.4	0.025	1.651	0.139	100%S
			Adhesive Madewell 1312F without Primer			
N17	281.962	212.6	0.005	0.609	0.104	100%S
N18*	291.696	315.2	0.001	1.746	0.159	100%S
N19	281.738	243.2	0.005	0.891	0.146	100%S
			Adhesive Madewell 1312F with Primer Madewell 927			
N17P	281.962	244.2	0.001	1.937	0.159	100%S
N18P*	291.696	329.4	0.008	2.097	0.183	100%S
N19P	281.738	183.4	0.002	0.982	0.119	100%S

Table 2. Set #2 – Temperature 70°F, Relative Humidity 65%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Mass of Mortar Layer pulled off grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
			Adhesive Sika 30 without Primer			
N21	274.124	108.2	0.011	0.618	0.149	100%S
N22	264.988	280.9	0.005	0.771	0.234	90%S+10%A
N23	288.71	276.2	0.014	0.550	0.051	95%S+5%A
			Adhesive Sika 30 with Primer Sika 55			
N21P*	274.124	235	0.011	1.882	0.144	100%S
N22P	264.988	113.4	0.013	1.033	0.129	95%S+5%A
N23P	288.71	187.4	0.009	0.430	0.050	10%S+90%A
			Adhesive Sika 32 without Primer			
N24	287.947	276.2	0.010	0.638	0.100	100%S
N25	285.454	403.1	0.003	0.405	0.034	100%S
N26	286.765	359.9	0.008	0.636	0.044	100%S
			Adhesive Sika 32 with Primer Sika 55			
N24P	287.947	301.5	0.008	0.705	0.059	100%S
N25P	285.454	293.6	0.008	0.447	0.054	95%S+5%A
N26P*	286.765	436	0.004	1.814	0.165	100%S
			Adhesive Madewell 1312F without Primer			
N27-SL	286.433	149.4	0.005	0.497	0.091	90%S+10%A
N28	265.607	161.3	0.012	1.011	0.164	100%S
N29	276.982	267.2	0.006	1.114	0.168	100%S
			Adhesive Madewell 1312F with Primer Madewell 927			
N27P	286.433	306	0.006	1.448	0.129	100%S
N28P*	265.607	167.3	0.005	1.85	0.161	100%S
N29P*	276.982	233.6	0.007	2.103	0.159	100%S

Table 3. Set #3 – Temperature 70°F, Relative Humidity 80%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer						
N31	279.708	223.4	0.010	0.320	0.097	20%A+80%S
N32	284.493	187	0.009	1.385	0.154	98%S+20%A
N33	275.726	167.9	0.003	1.119	0.124	95%S+5%A
Adhesive Sika 30 with Primer Sika 55						
N31P	279.708	91.11	0.008	0.155	0.019	10%S+90%A
N32P	284.493	23	0.009	0.461	0.080	66%S+34%A
N33P	275.726	66.47	0.008	0.223	0.052	20%S+80%A
Adhesive Sika 32 without Primer						
N34	286.264	268.7	0.002	1.121	0.105	100%S
N35	283.979	287.4	0.01	1.060	0.108	100%S
N36	285.642	221.2	0.003	1.409	0.130	100%S
Adhesive Sika 32 with Primer Sika 55						
N34P	286.264	280.9	0.006	0.876	0.094	100%S
N35P	283.979	268.3	0.004	0.866	0.099	100%S
N36P	285.642	390.6	0.003	0.345	0.055	100%S
Adhesive Madewell 1312F without Primer						
N37	280.439	184.3	0.005	0.731	0.088	100%S
N38	288.469	136	0.002	0.374	0.064	98%S+2%A
N39	270.004	128.5	0.002	0.845	0.151	95%S+5%A
Adhesive Madewell 1312F with Primer Madewell 927						
N37P	280.439	261.2	0.004	0.876	0.109	100%S
N38P	288.469	298.5	0.004	0.809	0.084	100%S
N39P	270.004	194.2	0.004	1.221	0.117	100%S

Table 4. Set #4 – Temperature 70ºF, Relative Humidity 95%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer
N41	285.319	336.8	0.014	0.282	0.052	15%S+85%A
N42	276.686	88.19	0.006	0.315	0.045	10%S+90%A
N43	290.384	143.2	0.019	0.975	0.109	95%S+5%A
Adhesive Sika 30 with Primer Sika 55
N41P	285.319	144.1	0.015	0.481	0.059	90%S+10%A
N42P	276.686	134.9	0.004	0.285	0.062	50%S+50%A
N43P	290.384	156.3	0.008	0.825	0.114	40%S+60%A
Adhesive Sika 32 without Primer
N44	286.217	355.8	0.004	0.521	0.053	100%S
N45*	279.680	242.5	0.002	1.887	0.149	100%S
N46*	273.337	200.7	0.003	1.998	0.219	100%S
Adhesive Sika 32 with Primer Sika 55
N44P	286.217	306.2	0.003	1.082	0.122	100%S
N45P	279.680	314.6	0.002	0.846	0.094	100%S
N46P	273.337	297.7	0.004	1.405	0.178	100%S
Adhesive Madewell 1312F without Primer
N47	278.662	200.7	0.009	0.892	0.118	96%S+4%A
N48	289.921	315.4	0.009	0.838	0.089	100%S
N49	281.559	229.8	0.005	1.422	0.169	100%S
Adhesive Madewell 1312F with Primer Madewell 927
N47P	278.662	304.2	0.005	1.272	0.132	100%S
N48P*	289.921	369	0.004	1.924	0.139	100%S
N49P	281.559	264.2	0.004	1.189	0.096	100%S

Table 5. Set #5 – Temperature 85ºF, Relative Humidity 50%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
			Adhesive Sika 30 without Primer			
N51X	280.141	0	0.016	0.866	0.118	85%S+15%A
N52	281.79	161.1	0.010	0.976	0.074	80%S+20%A
N53	276.78	82.5	0.030	0.978	0.059	70%S+30%A
			Adhesive Sika 30 with Primer Sika 55			
N51P	280.141	130.4	0.035	1.330	0.102	98%S+2%A
N52P	281.79	91.6	0.012	0.942	0.093	75%S+25%A
N53P	276.78	181.6	0.019	0.879	0.069	80%S+20%A
			Adhesive Sika 32 without Primer			
N54	281.776	332.8	0.013	0.725	0.042	100%S
N55	279.558	273.8	0.017	0.837	0.064	100%S
N56	288.795	317.7	0.003	1.147	0.112	100%S
			Adhesive Sika 32 with Primer Sika 55			
N54P	281.776	389	0.003	0.913	0.079	100%S
N55P*	279.558	252.8	0.005	1.686	0.099	100%S
N56P*	288.795	483.8	0.005	1.677	0.124	100%S
			Adhesive Madewell 1312F without Primer			
N57	287.163	406.7	0.004	0.561	0.062	98%S+2%A
N58	290.875	291.5	0.005	0.525	0.067	100%S
N59	288.471	170	0.005	0.396	0.043	100%S
			Adhesive Madewell 1312F with Primer Madewell 927			
N57PX	287.163	0	0.006	0.085	0.090	100%A
N58P	290.875	458.3	0.004	0.633	0.075	98%S+2%A
N59P	288.471	330.3	0.003	1.270	0.123	100%S

Table 6. Set #6 – Temperature 85°F, Relative Humidity 65%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
			Adhesive Sika 30 without Primer			
N61*	292.429	237.6	0.007	1.686	0.173	100%S
N62	288.232	180.2	0.008	1.135	0.126	90%S+10%A
N63	282.199	280.9	0.016	1.157	0.141	100%S
			Adhesive Sika 30 with Primer Sika 55			
N61P	292.429	98.5	0.013	0.220	0.055	20%S+80%A
N62P	288.232	178.7	0.021	0.881	0.114	90%S+10%A
N63P	282.199	198.9	0.009	0.287	0.141	60%S+40%A
			Adhesive Sika 32 without Primer			
N64	291.673	394.6	0.002	1.032	0.114	100%S
N65	289.440	232.8	0.003	1.301	0.104	100%S
N66*	288.040	281.3	0.004	2.027	0.159	100%S
			Adhesive Sika 32 with Primer Sika 55			
N64P	291.673	312.6	0.006	0.907	0.083	90%S+10%A
N65P*	289.440	303.2	0.009	1.697	0.129	98%S+2%A
N66P	288.040	319.9	0.004	1.380	0.147	100%S
			Adhesive Madewell 1312F without Primer			
N67*	289.809	277.9	0.011	2.105	0.207	100%S
N68 SL	286.662	253.7	0.009	0.411	0.061	75%S+25%A
N69	292.428	223.2	0.004	0.922	0.124	100%S
			Adhesive Madewell 1312F with Primer Madewell 927			
N67P*	289.809	256	0.002	1.731	0.144	100%S
N68P	286.662	259.1	0.008	0.747	0.083	100%S
N69P	292.428	329.1	0.007	0.908	0.094	100%S

Table 7. Set #7 – Temperature 85°F, Relative Humidity 80%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer						
N71	290.506	297.9	0.026	1.287	0.112	100%S
N72	289.865	133.7	0.011	0.535	0.097	80%S+20%A
N73	293.065	180	0.005	0.926	0.109	98%S+2%A
Adhesive Sika 30 with Primer Sika 55						
N71P	290.506	91.4	0.008	0.245	0.056	20%S+80%A
N72P	289.865	57.72	0.017	0.420	0.069	25%S+75%A
N73P	293.065	299.9	0.029	0.814	0.097	100%S
Adhesive Sika 32 without Primer						
N74	281.978	409.5	0.005	0.473	0.045	100%S
N75*	292.584	340.1	0.007	3.947	0.239	100%S
N76	286.958	394.5	0.005	0.451	0.046	95%S+5%A
Adhesive Sika 32 with Primer Sika 55						
N74P	281.978	405.1	0.006	0.508	0.084	90%S+10%A
N75P*	292.584	439.2	0.009	2.135	0.171	95%S+5%A
N76P*	286.958	373.7	0.005	2.640	0.220	100%S
Adhesive Madewell 1312F without Primer						
N77	285.693	381.5	0.005	0.798	0.107	100%S
N78*	292.739	320.8	0.003	1.557	0.112	100%S
N79	283.421	375.4	0.007	0.670	0.094	100%S
Adhesive Madewell 1312F with Primer Madewell 927						
N77P	285.693	438.3	0.008	0.471	0.059	100%S
N78P	292.739	258.3	0.003	0.843	0.100	100%S
N79P	283.421	393.6	0.003	0.519	0.065	100%S

Table 8. Set #8 – Temperature 85°F, Relative Humidity 95%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer					
N81	284.219	116.9	0.020	0.633	0.089	90%S+10%A
N82	285.349	271.3	0.024	0.585	0.050	100%S
N83	282.322	167.300	0.014	1.202	0.144	98%S+2%A
Adhesive Sika 30 with Primer Sika 55					
N81P	284.219	101.2	0.015	0.727	0.119	90%S+10%A
N82P	285.349	301.7	0.018	0.435	0.049	100%S
N83P	282.322	287.4	0.013	0.670	0.112	90%S+10%A
Adhesive Sika 32 without Primer					
N84	291.642	330.1	0.007	1.240	0.1	100%S
N85	294.170	335.4	0.003	1.395	0.089	100%S
N86	288.356	326.3	0.003	1.512	0.114	100%S
Adhesive Sika 32 with Primer Sika 55					
N84P*	291.642	318	0.003	2.227	0.189	100%S
N85P*	294.170	280.9	0.005	1.514	0.114	100%S
N86P*	288.356	270.6	0.003	1.697	0.171	100%S
Adhesive Madewell 1312F without Primer					
N87 SL	290.119	231.5	0.005	1.105	0.140	100%S
N88	292.453	231.8	0.007	0.815	0.104	95%S+5%A
N89 SL	291.940	307.4	0.003	1.070	0.127	100%S
Adhesive Madewell 1312F with Primer Madewell 927					
N87P	290.119	332.1	0.004	1.410	0.126	100%S
N88P	292.453	337.6	0.009	1.000	0.114	100%S
N89P*	291.940	370.6	0.004	2.720	0.199	100%S

Table 9. Set #9 – Temperature 100ºF, Relative Humidity 50%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer						
N91	287.858	147.2	0.008	0.349	0.061	60%S+40%A
N92	289.315	212.3	0.012	0.618	0.060	100%S
N93	282.628	134.5	0.012	0.555	0.189	80%S+20%A
Adhesive Sika 30 with Primer Sika 55						
N91P	287.858	65.48	0.014	0.302	0.057	30%S+70%A
N92P	289.315	117.2	0.010	0.700	0.076	95%S+5%A
N93P	282.628	204.8	0.011	0.530	0.055	95%S+5%A
Adhesive Sika 32 without Primer						
N94*	280.561	322.5	0.004	1.715	0.161	100%S
N95	283.215	300.9	0.002	0.445	0.034	100%S
N96	279.572	302	0.004	0.423	0.049	100%S
Adhesive Sika 32 with Primer Sika 55						
N94P	280.561	341.6	0.005	0.440	0.040	100%S
N95P*	283.215	319.5	0.004	2.075	0.214	100%S
N96P	279.572	348.7	0.003	0.489	0.066	100%S
Adhesive Madewell 1312F without Primer						
N97R	280.561	352.0	0.005	0.497	0.070	98%S+2%A
N98R	283.215	277.0	0.004	0.509	0.085	100S
N99R	279.572	453.0	0.002	0.468	0.060	100%
Adhesive Madewell 1312F with Primer Madewell 927						
N97PR	286.211	428.200	0.003	0.969	0.135	100%
N98PR	281.546	468.000	0.009	0.642	0.095	100%
N99PR	290.306	412.800	0.003	0.236	0.057	98%S+2%A

Table 10. Set #10 – Temperature 100ºF, Relative Humidity 65%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer						
N101	307.138	129.4	0.010	0.395	0.055	70%S+30%A
N102	293.312	164.1	0.012	0.590	0.071	95%S+5%A
N103	304.477	213.7	0.009	1.163	0.122	100%S
Adhesive Sika 30 with Primer Sika 55						
N101P	307.138	102	0.015	0.385	0.066	70%S+30%A
N102P	293.312	93.93	0.012	0.597	0.073	90%S+10%A
N103P	304.477	311.8	0.011	0.900	0.114	95%S+5%A
Adhesive Sika 32 without Primer						
N104	301.486	403.9	0.003	0.725	0.090	100%S
N105*	289.653	276.9	0.004	3.110	0.245	100%S
N106	298.328	329.1	0.010	0.982	0.114	98%S+2%A
Adhesive Sika 32 with Primer Sika 55						
N104P	301.486	382	0.005	0.732	0.085	100%S
N105P	289.653	313.6	0.005	0.750	0.081	100%S
N106P	298.328	305.8	0.006	0.565	0.054	98%S+2%A
Adhesive Madewell 1312F without Primer						
N107	287.550	243.8	0.003	0.33	0.069	95%S+5%A
N108*	285.745	320.4	0.004	1.565	0.168	100%S
N109	287.488	342.7	0.003	0.552	0.072	100%S
Adhesive Madewell 1312F with Primer Madewell 927						
N107P	287.550	292.2	0.03	0.530	0.067	95%S+5%A
N108P	285.745	312.5	0.002	0.270	0.090	40%S+60%A
N109P	287.488	327.9	0.004	0.619	0.075	100%S

Table 11. Set #11 – Temperature 100°F, Relative Humidity 80%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer						
N111	288.235	269	0.018	1.100	0.116	100%S
N112	288.365	144.9	0.012	0.435	0.073	70%S+30%A
N113	297.109	113	0.018	0.635	0.124	60%S+40%A
Adhesive Sika 30 with Primer Sika 55						
N111P	288.235	223.8	0.008	0.733	0.091	60%S+40%A
N112P	288.365	189.5	0.011	0.250	0.043	5%S+95%A
N113P	297.109	309	0.012	0.625	0.074	97%S+3%A
Adhesive Sika 32 without Primer						
N114	292.419	315.2	0.006	1.230	0.163	100%S
N115	297.120	294.9	0.004	0.250	0.034	100%S(thin lyr)
N116	305.989	259.3	0.009	0.252	0.018	100%S(thin lyr)
Adhesive Sika 32 with Primer Sika 55						
N114P	292.419	288.2	0.008	0.325	0.031	50%S+50%A
N115P	297.120	331.5	0.008	1.468	0.149	100%S
N116P	305.989	445.9	0.006	0.402	0.073	100%S(thin lyr)
Adhesive Madewell 1312F without Primer						
N117	306.328	429.4	0.004	0.345	0.087	75%S+25%A
N118 SL	309.997	265.1	0.005	0.785	0.126	100%S
N119 SL	287.058	194.5	0.003	0.955	0.124	100%S
Adhesive Madewell 1312F with Primer Madewell 927						
N117P	306.328	287.1	0.007	1.117	0.133	100%S
N118P	309.997	371.9	0.008	0.255	0.030	100%S(thin lyr)
N119P	287.058	350.3	0.003	0.630	0.074	98%S+2%A

Table 12. Set #12 – Temperature 100ºF, Relative Humidity 95%.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Adhesive Sika 30 without Primer						
N121*	302.726	176.5	0.020	1.628	0.177	100%S
N122	300.294	157.9	0.021	0.268	0.067	10%S+90%A
N123X	305.358	0	0.012	0.020	0.013	100%S
Adhesive Sika 30 with Primer Sika 55						
N121P	302.726	220.4	0.028	0.538	0.108	90%S+10%A
N122P	300.294	250.1	0.016	0.604	0.080	98%S+2%A
N123P	305.358	279.9	0.016	0.335	0.059	70%S+30%A
Adhesive Sika 32 without Primer						
N124 SL	307.822	63.03	0.02	0.091	0.018	1%S+99%A
N125 SL	289.640	48.97	0.017	0.040	0.012	100%C
N126	305.451	122.7	0.003	0.086	0.038	5%S+95%A
Adhesive Sika 32 with Primer Sika 55						
N124PX	307.822	0	0.012	0.100	0.020	100%A
N125P	289.640	86.07	0.027	0.141	0.045	1%S+99%A
N126P	305.451	357.9	0.004	0.350	0.065	90%S+10%A
Adhesive Madewell 1312F without Primer						
N127X	290.985	0	0.003	0.002	0.004	100%A
N128 SL	323.841	111.8	0.011	0.098	0.040	5%S+95%A
N129 SL	298.946	125.2	0.010	0.068	0.068	2%S+98%A
Adhesive Madewell 1312F with Primer Madewell 927						
N127P*	290.985	209	0.003	1.608	0.273	100%S
N128P	323.841	364.2	0.009	0.295	0.081	20%S+80%A
N129P	298.946	359.3	0.017	0.053	0.053	50%S+50%A

Table 13. Adhesive Sika 30 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50 %		Without Primer				
N11	280.312	168.3	0.012	0.573	0.058	100%S
N12	279.058	321	0.008	0.716	0.104	100%S
N13*	275.824	275.2	0.012	2.639	0.199	100%S
		With Primer Sika 55				
N11P	280.312	223	0.020	0.594	0.077	100%S
N12P*	279.058	297.7	0.010	2.595	0.179	100%S
N13P*	275.824	332.9	0.007	3.087	0.213	100%S
RH=65 %		Without Primer				
N21	274.124	108.2	0.011	0.618	0.149	100%S
N22	264.988	280.9	0.005	0.771	0.234	90%S+10%A
N23	288.71	276.2	0.014	0.550	0.051	95%S+5%A
		With Primer Sika 55				
N21P*	274.124	235	0.011	1.882	0.144	100%S
N22P	264.988	113.4	0.013	1.033	0.129	95%S+5%A
N23P	288.71	187.4	0.009	0.430	0.050	10%S+90%A
RH=80 %		Without Primer				
N31	279.708	223.4	0.010	0.320	0.097	20%A+80%S
N32	284.493	187	0.009	1.385	0.154	98%S+20%A
N33	275.726	167.9	0.003	1.119	0.124	95%S+5%A
		With Primer Sika 55				
N31P	279.708	91.11	0.008	0.155	0.019	10%S+90%A
N32PX	284.493	0	0.009	0.461	0.080	66%S+34%A
N33P	275.726	166.47	0.008	0.223	0.052	20%S+80%A
RH=95 %		Without Primer				
N41	285.319	336.8	0.014	0.282	0.052	15%S+85%A
N42	276.686	88.19	0.006	0.315	0.045	10%S+90%A
N43	290.384	143.2	0.019	0.975	0.109	95%S+5%A
		With Primer Sika 55				
N41P	285.319	144.1	0.015	0.481	0.059	90%S+10%A
N42P	276.686	134.9	0.004	0.285	0.062	50%S+50%A
N43P	290.384	156.3	0.008	0.825	0.114	40%S+60%A

Table 13A. Adhesive Sika 30 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N11	280.312	168.3	0.012	0.573	0.058	100%S
N12	279.058	321	0.008	0.716	0.104	100%S
N13*	275.824	275.2	0.012	2.639	0.199	100%S
RH=65%						
N21	274.124	108.2	0.011	0.618	0.149	100%S
N22	264.988	280.9	0.005	0.771	0.234	90%S+10%A
N23	288.71	276.2	0.014	0.550	0.051	95%S+5%A
RH=80%						
N31	279.708	223.4	0.010	0.320	0.097	20%A+80%S
N32	284.493	187	0.009	1.385	0.154	98%S+20%A
N33	275.726	167.9	0.003	1.119	0.124	95%S+5%A
RH=95%						
N41	285.319	336.8	0.014	0.282	0.052	15%S+85%A
N42	276.686	88.19	0.006	0.315	0.045	10%S+90%A
N43	290.384	143.2	0.019	0.975	0.109	95%S+5%A
		With Primer Sika 55				
RH=50%						
N11P	280.312	223	0.020	0.594	0.077	100%S
N12P*	279.058	297.7	0.010	2.595	0.179	100%S
N13P*	275.824	332.9	0.007	3.087	0.213	100%S
RH=65%						
N21P*	274.124	235	0.011	1.882	0.144	100%S
N22P	264.988	113.4	0.013	1.033	0.129	95%S+5%A
N23P	288.71	187.4	0.009	0.430	0.050	10%S+90%A
RH=80%						
N31P	279.708	91.11	0.008	0.155	0.019	10%S+90%A
N32PX	284.493	0	0.009	0.461	0.080	66%S+34%A
N33P	275.726	166.47	0.008	0.223	0.052	20%S+80%A
RH=95%						
N41P	285.319	144.1	0.015	0.481	0.059	90%S+10%A
N42P	276.686	134.9	0.004	0.285	0.062	50%S+50%A
N43P	290.384	156.3	0.008	0.825	0.114	40%S+60%A

Table 13B. Adhesive Sika 30 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Without Primer						
RH=50%						
N11	280.312	168.3	0.012	0.573	0.058	100%S
N12	279.058	321	0.008	0.716	0.104	100%S
N13*	275.824	275.2	0.012	2.639	0.199	100%S
Average		**254.83**	**0.011**	**1.309**	**0.120**	
RH=65%						
N21	274.124	108.2	0.011	0.618	0.149	100%S
N22	264.988	280.9	0.005	0.771	0.234	90%S+10%A
N23	288.71	276.2	0.014	0.550	0.051	95%S+5%A
Average		**221.77**	**0.010**	**0.646**	**0.145**	
RH=80%						
N31	279.708	223.4	0.010	0.320	0.097	20%A+80%S
N32	284.493	187	0.009	1.385	0.154	98%S+20%A
N33	275.726	167.9	0.003	1.119	0.124	95%S+5%A
Average		**192.77**	**0.007**	**0.941**	**0.125**	
RH=95%						
N41	285.319	336.8	0.014	0.282	0.052	15%S+85%A
N42	276.686	88.19	0.006	0.315	0.045	10%S+90%A
N43	290.384	143.2	0.019	0.975	0.109	95%S+5%A
Average		**189.40**	**0.013**	**0.524**	**0.069**	
With Primer Sika 55						
RH=50%						
N11P	280.312	223	0.020	0.594	0.077	100%S
N12P*	279.058	297.7	0.010	2.595	0.179	100%S
N13P*	275.824	332.9	0.007	3.087	0.213	100%S
Average		**284.53**	**0.012**	**2.092**	**0.156**	
RH=65%						
N21P*	274.124	235	0.011	1.882	0.144	100%S
N22P	264.988	113.4	0.013	1.033	0.129	95%S+5%A
N23P	288.71	187.4	0.009	0.430	0.050	10%S+90%A
Average		**178.6**	**0.011**	**1.115**	**0.108**	
RH=80%						
N31P	279.708	91.11	0.008	0.155	0.019	10%S+90%A
N32PX	284.493	0	0.009	0.461	0.080	66%S+34%A
N33P	275.726	166.47	0.008	0.223	0.052	20%S+80%A
Average		**128.79**	**0.008**	**0.280**	**0.050**	
RH=95%						
N41P	285.319	144.1	0.015	0.481	0.059	90%S+10%A
N42P	276.686	134.9	0.004	0.285	0.062	50%S+50%A
N43P	290.384	156.3	0.008	0.825	0.114	40%S+60%A
Average		**145.1**	**0.009**	**0.530**	**0.078**	

Table 13C. Adhesive Sika 30 at Temperature 70°F.

	Average Peak Load to pull off dolly pounds	Average Adhesive Film Thickness inch	Average Pulled off Mass of Mortar Layer grams	Average Max Height of Mortar Layer inch
RH%	Without Primer			
50	254.83	0.011	1.309	0.12
65	221.77	0.01	0.646	0.145
80	192.77	0.007	0.941	0.125
95	189.4	0.013	0.524	0.069
	With Primer Sika 55			
50	284.53	0.012	2.092	0.156
65	178.6	0.011	1.115	0.108
80	128.79	0.008	0.28	0.05
95	145.1	0.009	0.53	0.078

Data rearranged for plotting.

RH%	No Primer	With Primer
50	254.83	284.53
65	221.77	178.6
80	192.77	128.79
95	189.4	145.1

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Table 14. Adhesive Sika 30 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive
RH=50%		Without Primer				
N51X	280.141	0	0.016	0.866	0.118	85%S+15%A
N52	281.79	161.1	0.010	0.976	0.074	80%S+20%A
N53	276.78	82.5	0.030	0.978	0.059	70%S+30%A
		With Primer Sika 55				
N51P	280.141	130.4	0.035	1.330	0.102	98%S+2%A
N52P	281.79	91.6	0.012	0.942	0.093	75%S+25%A
N53P	276.78	181.6	0.019	0.879	0.069	80%S+20%A
RH=65%		Without Primer				
N61*	292.429	237.6	0.007	1.686	0.173	100%S
N62	288.232	180.2	0.008	1.135	0.126	90%S+10%A
N63	282.199	280.9	0.016	1.157	0.141	100%S
		With Primer Sika 55				
N61P	292.429	98.5	0.013	0.220	0.055	20%S+80%A
N62P	288.232	178.7	0.021	0.881	0.114	90%S+10%A
N63P	282.199	198.9	0.009	0.287	0.141	60%S+40%A
RH=80%		Without Primer				
N71	290.506	297.9	0.026	1.287	0.112	100%S
N72	289.865	133.7	0.011	0.535	0.097	80%S+20%A
N73	293.065	180	0.005	0.926	0.109	98%S+2%A
		With Primer Sika 55				
N71P	290.506	91.4	0.008	0.245	0.056	20%S+80%A
N72P	289.865	57.72	0.017	0.420	0.069	25%S+75%A
N73P	293.065	299.9	0.029	0.814	0.097	100%S
RH=95%		Without Primer				
N81	284.219	116.9	0.020	0.633	0.089	90%S+10%A
N82	285.349	271.3	0.024	0.585	0.050	100%S
N83	282.322	167.300	0.014	1.202	0.144	98%S+2%A
		With Primer Sika 55				
N81P	284.219	101.2	0.015	0.727	0.119	90%S+10%A
N82P	285.349	301.7	0.018	0.435	0.049	100%S
N83P	282.322	287.4	0.013	0.670	0.112	90%S+10%A

Table 14A. Adhesive Sika 30 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive
RH=50%		Without Primer				
N51X	280.141	0	0.016	0.866	0.118	85%S+15%A
N52	281.79	161.1	0.010	0.976	0.074	80%S+20%A
N53	276.78	82.5	0.030	0.978	0.059	70%S+30%A
RH=65%						
N61*	292.429	237.6	0.007	1.686	0.173	100%S
N62	288.232	180.2	0.008	1.135	0.126	90%S+10%A
N63	282.199	280.9	0.016	1.157	0.141	100%S
RH=80%						
N71	290.506	297.9	0.026	1.287	0.112	100%S
N72	289.865	133.7	0.011	0.535	0.097	80%S+20%A
N73	293.065	180	0.005	0.926	0.109	98%S+2%A
RH=95%						
N81	284.219	116.9	0.020	0.633	0.089	90%S+10%A
N82	285.349	271.3	0.024	0.585	0.050	100%S
N83	282.322	167.300	0.014	1.202	0.144	98%S+2%A
		With Primer Sika 55				
RH=50%						
N51P	280.141	130.4	0.035	1.330	0.102	98%S+2%A
N52P	281.79	91.6	0.012	0.942	0.093	75%S+25%A
N53P	276.78	181.6	0.019	0.879	0.069	80%S+20%A
RH=65%						
N61P	292.429	98.5	0.013	0.220	0.055	20%S+80%A
N62P	288.232	178.7	0.021	0.881	0.114	90%S+10%A
N63P	282.199	198.9	0.009	0.287	0.141	60%S+40%A
RH=80%						
N71P	290.506	91.4	0.008	0.245	0.056	20%S+80%A
N72P	289.865	57.72	0.017	0.420	0.069	25%S+75%A
N73P	293.065	299.9	0.029	0.814	0.097	100%S
RH=95%						
N81P	284.219	101.2	0.015	0.727	0.119	90%S+10%A
N82P	285.349	301.7	0.018	0.435	0.049	100%S
N83P	282.322	287.4	0.013	0.670	0.112	90%S+10%A

Table 14B. Adhesive Sika 30 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive
Without Primer						
RH=50%						
N51X	280.141	0	0.016	0.866	0.118	85%S+15%A
N52	281.79	161.1	0.010	0.976	0.074	80%S+20%A
N53	276.78	82.5	0.030	0.978	0.059	70%S+30%A
Average		**121.8**	**0.019**	**0.94**	**0.084**	
RH=65%						
N61*	292.429	237.6	0.007	1.686	0.173	100%S
N62	288.232	180.2	0.008	1.135	0.126	90%S+10%A
N63	282.199	280.9	0.016	1.157	0.141	100%S
Average		**232.9**	**0.010**	**1.326**	**0.147**	
RH=80%						
N71	290.506	297.9	0.026	1.287	0.112	100%S
N72	289.865	133.7	0.011	0.535	0.097	80%S+20%A
N73	293.065	180	0.005	0.926	0.109	98%S+2%A
Average		**203.867**	**0.014**	**0.916**	**0.106**	
RH=95%						
N81	284.219	116.9	0.020	0.633	0.089	90%S+10%A
N82	285.349	271.3	0.024	0.585	0.050	100%S
N83	282.322	167.300	0.014	1.202	0.144	98%S+2%A
Average		**185.167**	**0.019**	**0.807**	**0.094**	
With Primer Sika 55						
RH=50%						
N51P	280.141	130.4	0.035	1.330	0.102	98%S+2%A
N52P	281.79	91.6	0.012	0.942	0.093	75%S+25%A
N53P	276.78	181.6	0.019	0.879	0.069	80%S+20%A
Average		**134.533**	**0.022**	**1.050**	**0.088**	
RH=65%						
N61P	292.429	98.5	0.013	0.220	0.055	20%S+80%A
N62P	288.232	178.7	0.021	0.881	0.114	90%S+10%A
N63P	282.199	198.9	0.009	0.287	0.141	60%S+40%A
Average		**158.7**	**0.014**	**0.463**	**0.103**	
RH=80%						
N71P	290.506	91.4	0.008	0.245	0.056	20%S+80%A
N72P	289.865	57.72	0.017	0.420	0.069	25%S+75%A
N73P	293.065	299.9	0.029	0.814	0.097	100%S
Average		**149.673**	**0.018**	**0.493**	**0.074**	
RH=95%						
N81P	284.219	101.2	0.015	0.727	0.119	90%S+10%A
N82P	285.349	301.7	0.018	0.435	0.049	100%S
N83P	282.322	287.4	0.013	0.670	0.112	90%S+10%A
Average		**230.1**	**0.015**	**0.611**	**0.093**	

Table 14C. Adhesive Sika 30 at Temperature 85°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
RH%	Without Primer			
50	121.8	0.019	0.94	0.084
65	232.9	0.01	1.326	0.147
80	203.867	0.014	0.916	0.106
95	185.167	0.019	0.807	0.094
	With Primer Sika55			
50	134.533	0.022	1.05	0.088
65	158.7	0.014	0.463	0.103
80	149.673	0.018	0.493	0.074
95	230.1	0.015	0.611	0.093

Data rearranged for plotting

RH%	No Primer	With Primer
50	121.8	134.533
65	232.9	158.7
80	203.867	149.673
95	185.167	230.1

Table 15. Adhesive Sika 30 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50%		Without Primer				
N91	287.858	147.2	0.008	0.349	0.061	60%S+40%A
N92	289.315	212.3	0.012	0.618	0.060	100%S
N93	282.628	134.5	0.012	0.555	0.189	80%S+20%A
		With Primer Sika 55				
N91P	287.858	65.48	0.014	0.302	0.057	30%S+70%A
N92P	289.315	117.2	0.010	0.700	0.076	95%S+5%A
N93P	282.628	204.8	0.011	0.530	0.055	95%S+5%A
RH=65%		Without Primer				
N101	307.138	129.4	0.01	0.395	0.055	70%S+30%A
N102	293.312	164.1	0.012	0.59	0.071	95%S+5%A
N103	304.477	213.7	0.009	1.163	0.122	100%S
		With Primer Sika 55				
N101P	307.138	102	0.015	0.385	0.066	70%S+30%A
N102P	293.312	93.93	0.012	0.597	0.073	90%S+10%A
N103P	304.477	311.8	0.011	0.9	0.114	95%S+5%A
RH=80%		Without Primer				
N111	288.235	269	0.018	1.1	0.116	100%S
N112	288.365	144.9	0.012	0.435	0.073	70%S+30%A
N113	297.109	113	0.018	0.635	0.124	60%S+40%A
		With Primer Sika 55				
N111P	288.235	223.8	0.008	0.733	0.091	60%S+40%A
N112P	288.365	189.5	0.011	0.25	0.043	5%S+95%A
N113P	297.109	309	0.012	0.625	0.074	97%S+3%A
RH=95%		Without Primer				
N121*	302.726	176.5	0.02	1.628	0.177	100%S
N122	300.294	157.9	0.021	0.268	0.067	10%S+90%A
N123X	305.358	0	0.012	0.02	0.013	100%S
		With Primer Sika 55				
N121P	302.726	220.4	0.028	0.538	0.108	90%S+10%A
N122P	300.294	250.1	0.016	0.604	0.08	98%S+2%A
N123P	305.358	279.9	0.016	0.335	0.059	70%S+30%A

Table 15A. Adhesive Sika 30 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N91	287.858	147.2	0.008	0.349	0.061	60%S+40%A
N92	289.315	212.3	0.012	0.618	0.060	100%S
N93	282.628	134.5	0.012	0.555	0.189	80%S+20%A
RH=65%						
N101	307.138	129.4	0.01	0.395	0.055	70%S+30%A
N102	293.312	164.1	0.012	0.59	0.071	95%S+5%A
N103	304.477	213.7	0.009	1.163	0.122	100%S
RH=80%						
N111	288.235	269	0.018	1.1	0.116	100%S
N112	288.365	144.9	0.012	0.435	0.073	70%S+30%A
N113	297.109	113	0.018	0.635	0.124	60%S+40%A
RH=95%						
N121*	302.726	176.5	0.02	1.628	0.177	100%S
N122	300.294	157.9	0.021	0.268	0.067	10%S+90%A
N123X	305.358	0	0.012	0.02	0.013	100%S
		With Primer Sika 55				
RH=50%						
N91P	287.858	65.48	0.014	0.302	0.057	30%S+70%A
N92P	289.315	117.2	0.010	0.700	0.076	95%S+5%A
N93P	282.628	204.8	0.011	0.530	0.055	95%S+5%A
RH=65%						
N101P	307.138	102	0.015	0.385	0.066	70%S+30%A
N102P	293.312	93.93	0.012	0.597	0.073	90%S+10%A
N103P	304.477	311.8	0.011	0.9	0.114	95%S+5%A
RH=80%						
N111P	288.235	223.8	0.008	0.733	0.091	60%S+40%A
N112P	288.365	189.5	0.011	0.25	0.043	5%S+95%A
N113P	297.109	309	0.012	0.625	0.074	97%S+3%A
RH=95%						
N121P	302.726	220.4	0.028	0.538	0.108	90%S+10%A
N122P	300.294	250.1	0.016	0.604	0.08	98%S+2%A
N123P	305.358	279.9	0.016	0.335	0.059	70%S+30%A

Table 15B. Adhesive Sika 30 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N91	287.858	147.2	0.008	0.349	0.061	60%S+40%A
N92	289.315	212.3	0.012	0.618	0.060	100%S
N93	282.628	134.5	0.012	0.555	0.189	80%S+20%A
Average		**164.7**	**0.011**	**0.507**	**0.103**	
RH=65%						
N101	307.138	129.4	0.01	0.395	0.055	70%S+30%A
N102	293.312	164.1	0.012	0.59	0.071	95%S+5%A
N103	304.477	213.7	0.009	1.163	0.122	100%S
Average		**169.1**	**0.010**	**0.716**	**0.083**	
RH=80%						
N111	288.235	269	0.018	1.1	0.116	100%S
N112	288.365	144.9	0.012	0.435	0.073	70%S+30%A
N113	297.109	113	0.018	0.635	0.124	60%S+40%A
Average		**175.6**	**0.016**	**0.723**	**0.104**	
RH=95%						
N121*	302.726	176.5	0.02	1.628	0.177	100%S
N122	300.294	157.9	0.021	0.268	0.067	10%S+90%A
N123X	305.358	0	0.012	0.02	0.013	100%S
Average		**167.2**	**0.018**	**0.639**	**0.086**	
		With Primer Sika 55				
RH=50%						
N91P	287.858	65.48	0.014	0.302	0.057	30%S+70%A
N92P	289.315	117.2	0.010	0.700	0.076	95%S+5%A
N93P	282.628	204.8	0.011	0.530	0.055	95%S+5%A
Average		**129.16**	**0.012**	**0.511**	**0.063**	
RH=65%						
N101P	307.138	102	0.015	0.385	0.066	70%S+30%A
N102P	293.312	93.93	0.012	0.597	0.073	90%S+10%A
N103P	304.477	311.8	0.011	0.9	0.114	95%S+5%A
Average		**169.2**	**0.013**	**0.627**	**0.084**	
RH=80%						
N111P	288.235	223.8	0.008	0.733	0.091	60%S+40%A
N112P	288.365	189.5	0.011	0.25	0.043	5%S+95%A
N113P	297.109	309	0.012	0.625	0.074	97%S+3%A
Average		**240.8**	**0.010**	**0.536**	**0.069**	
RH=95%						
N121P	302.726	220.4	0.028	0.538	0.108	90%S+10%A
N122P	300.294	250.1	0.016	0.604	0.08	98%S+2%A
N123P	305.358	279.9	0.016	0.335	0.059	70%S+30%A
Average		**250.1**	**0.020**	**0.492**	**0.082**	

Table 15C. Adhesive Sika 30 at Temperature 100°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
	Without Primer			
RH%				
50	164.7	0.011	0.507	0.103
65	169.1	0.010	0.716	0.083
80	175.6	0.016	0.723	0.104
95	167.2	0.018	0.639	0.086
	With Primer Sika 55			
RH%				
50	129.16	0.012	0.511	0.063
65	169.2	0.013	0.627	0.084
80	240.8	0.010	0.536	0.069
95	250.1	0.020	0.492	0.082

Data rearranged for plotting

RH%	No Primer	With Primer
50	164.7	129.16
65	169.1	169.2
80	175.6	240.8
95	167.2	250.1

Table 16. Adhesive Sika 32 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50%		Without Primer				
N14	270.399	372.1	0.002	1.008	0.084	100%S
N15	282.337	278.1	0.002	1.379	0.151	100%S
N16*	291.342	452.6	0.004	3.530	0.192	100%S
		With Primer				
N14P*	270.399	390.9	0.001	2.727	0.194	100%S
N15P	282.337	340.3	0.002	0.532	0.06	100%S
N16P	291.342	411.4	0.025	1.651	0.139	100%S
RH=65%		Without Primer				
N24	287.947	276.2	0.01	0.638	0.1	100%S
N25	285.454	403.1	0.003	0.405	0.034	100%S
N26	286.765	359.9	0.008	0.636	0.044	100%S
		With Primer Sika 55				
N24P	287.947	301.5	0.008	0.705	0.059	100%S
N25P	285.454	293.6	0.008	0.447	0.054	95%S+5%A
N26P*	286.765	436	0.004	1.814	0.165	100%S
RH=80%		Without Primer				
N34	286.264	268.7	0.002	1.121	0.105	100%S
N35	283.979	287.4	0.01	1.06	0.108	100%S
N36	285.642	221.2	0.003	1.409	0.13	100%S
		With Primer Sika 55				
N34P	286.264	280.9	0.006	0.876	0.094	100%S
N35P	283.979	268.3	0.004	0.866	0.099	100%S
N36P	285.642	390.6	0.003	0.345	0.055	100%S
RH=95%		Without Primer				
N44	286.217	355.8	0.004	0.521	0.053	100%S
N45*	279.68	242.5	0.002	1.887	0.149	100%S
N46*	273.337	200.7	0.003	1.998	0.219	100%S
		With Primer Sika 55				
N44P	286.217	306.2	0.003	1.082	0.122	100%S
N45P	279.68	314.6	0.002	0.846	0.094	100%S
N46P	273.337	297.7	0.004	1.405	0.178	100%S

Table 16A. Adhesive Sika 32 at Temperature 70ºF.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N14	270.399	372.1	0.002	1.008	0.084	100%S
N15	282.337	278.1	0.002	1.379	0.151	100%S
N16*	291.342	452.6	0.004	3.530	0.192	100%S
RH=65%						
N24	287.947	276.2	0.010	0.638	0.100	100%S
N25	285.454	403.1	0.003	0.405	0.034	100%S
N26	286.765	359.9	0.008	0.636	0.044	100%S
RH=80%						
N34	286.264	268.7	0.002	1.121	0.105	100%S
N35	283.979	287.4	0.010	1.060	0.108	100%S
N36	285.642	221.2	0.003	1.409	0.130	100%S
RH=95%						
N44	286.217	355.8	0.004	0.521	0.053	100%S
N45*	279.68	242.5	0.002	1.887	0.149	100%S
N46*	273.337	200.7	0.003	1.998	0.219	100%S
		With Primer Sika 55				
RH=50%						
N14P*	270.399	390.9	0.001	2.727	0.194	100%S
N15P	282.337	340.3	0.002	0.532	0.06	100%S
N16P	291.342	411.4	0.025	1.651	0.139	100%S
RH-65%						
N24P	287.947	301.5	0.008	0.705	0.059	100%S
N25P	285.454	293.6	0.008	0.447	0.054	95%S+5%A
N26P*	286.765	436	0.004	1.814	0.165	100%S
RH=80%						
N34P	286.264	280.9	0.006	0.876	0.094	100%S
N35P	283.979	268.3	0.004	0.866	0.099	100%S
N36P	285.642	390.6	0.003	0.345	0.055	100%S
RH=95%						
N44P	286.217	306.2	0.003	1.082	0.122	100%S
N45P	279.68	314.6	0.002	0.846	0.094	100%S
N46P	273.337	297.7	0.004	1.405	0.178	100%S

Table 16B. Adhesive Sika 32 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Without Primer						
RH=50%						
N14	270.399	372.1	0.002	1.008	0.084	100%S
N15	282.337	278.1	0.002	1.379	0.151	100%S
N16*	291.342	452.6	0.004	3.530	0.192	100%S
Average		**367.6**	**0.003**	**1.972**	**0.142**	
RH=65%						
N24	287.947	276.2	0.010	0.638	0.100	100%S
N25	285.454	403.1	0.003	0.405	0.034	100%S
N26	286.765	359.9	0.008	0.636	0.044	100%S
Average		**346.4**	**0.007**	**0.560**	**0.059**	
RH=80%						
N34	286.264	268.7	0.002	1.121	0.105	100%S
N35	283.979	287.4	0.010	1.060	0.108	100%S
N36	285.642	221.2	0.003	1.409	0.130	100%S
Average		**259.1**	**0.005**	**1.197**	**0.114**	
RH=95%						
N44	286.217	355.8	0.004	0.521	0.053	100%S
N45*	279.68	242.5	0.002	1.887	0.149	100%S
N46*	273.337	200.7	0.003	1.998	0.219	100%S
Average		**266.3**	**0.003**	**1.469**	**0.140**	
With Primer Sika 55						
RH=50%						
N14P*	270.399	390.9	0.001	2.727	0.194	100%S
N15P	282.337	340.3	0.002	0.532	0.06	100%S
N16P	291.342	411.4	0.025	1.651	0.139	100%S
Average		**380.9**	**0.009**	**1.637**	**0.131**	
RH-65%						
N24P	287.947	301.5	0.008	0.705	0.059	100%S
N25P	285.454	293.6	0.008	0.447	0.054	95%S+5%A
N26P*	286.765	436	0.004	1.814	0.165	100%S
Average		**343.7**	**0.007**	**0.989**	**0.093**	
RH=80%						
N34P	286.264	280.9	0.006	0.876	0.094	100%S
N35P	283.979	268.3	0.004	0.866	0.099	100%S
N36P	285.642	390.6	0.003	0.345	0.055	100%S
Average		**313.3**	**0.004**	**0.696**	**0.083**	
RH=95%						
N44P	286.217	306.2	0.003	1.082	0.122	100%S
N45P	279.68	314.6	0.002	0.846	0.094	100%S
N46P	273.337	297.7	0.004	1.405	0.178	100%S
Average		**306.2**	**0.003**	**1.111**	**0.131**	

Table 16C. Adhesive Sika 32 at Temperature 70°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
Without Primer				
RH%				
50	367.6	0.003	1.972	0.142
65	346.4	0.007	0.56	0.059
80	259.1	0.005	1.197	0.114
95	266.3	0.003	1.469	0.14
With Primer Sika 55				
RH%				
50	380.9	0.009	1.637	0.131
65	343.7	0.007	0.989	0.093
80	313.3	0.004	0.696	0.083
95	306.2	0.003	1.111	0.131

Data rearranged for plotting

RH%	No Primer	With Primer
50	367.6	380.9
65	346.4	343.7
80	259.1	313.3
95	266.3	306.2

Table 17. Adhesive Sika 32 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50%		Without Primer				
N54	281.776	332.8	0.013	0.725	0.042	100%S
N55	279.558	273.8	0.017	0.837	0.064	100%S
N56	288.795	317.7	0.003	1.147	0.112	100%S
		With Primer Sika 55				
N54P	281.776	389	0.003	0.913	0.079	100%S
N55P*	279.558	252.8	0.005	1.686	0.099	100%S
N56P*	288.795	483.8	0.005	1.677	0.124	100%S
RH=65%		Without Primer				
N64	291.673	394.6	0.002	1.032	0.114	100%S
N65	289.44	232.8	0.003	1.301	0.104	100%S
N66*	288.04	281.3	0.004	2.027	0.159	100%S
		With Primer Sika 55				
N64P	291.673	312.6	0.006	0.907	0.083	90%S+10%A
N65P*	289.44	303.2	0.009	1.697	0.129	98%S+2%A
N66P	288.04	319.9	0.004	1.380	0.147	100%S
RH=80%		Without Primer				
N74	281.978	409.5	0.005	0.473	0.045	100%S
N75*	292.584	340.1	0.007	3.947	0.239	100%S
N76	286.958	394.5	0.005	0.451	0.046	95%S+5%A
		With Primer Sika 55				
N74P	281.978	405.1	0.006	0.508	0.084	90%S+10%A
N75P*	292.584	439.2	0.009	2.135	0.171	95%S+5%A
N76P*	286.958	373.7	0.005	2.640	0.22	100%S
RH=95%		Without Primer				
N84	291.642	330.1	0.007	1.240	0.100	100%S
N85	294.17	335.4	0.003	1.395	0.089	100%S
N86	288.356	326.3	0.003	1.512	0.114	100%S
		With Primer Sika 55				
N84P*	291.642	318	0.003	2.227	0.189	100%S
N85P*	294.17	280.9	0.005	1.514	0.114	100%S
N86P*	288.356	270.6	0.003	1.697	0.171	100%S

Table 17A. Adhesive Sika 32 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N54	281.776	332.8	0.013	0.725	0.042	100%S
N55	279.558	273.8	0.017	0.837	0.064	100%S
N56	288.795	317.7	0.003	1.147	0.112	100%S
RH=65%						
N64	291.673	394.6	0.002	1.032	0.114	100%S
N65	289.44	232.8	0.003	1.301	0.104	100%S
N66*	288.04	281.3	0.004	2.027	0.159	100%S
RH=80%						
N74	281.978	409.5	0.005	0.473	0.045	100%S
N75*	292.584	340.1	0.007	3.947	0.239	100%S
N76	286.958	394.5	0.005	0.451	0.046	95%S+5%A
RH=95%						
N84	291.642	330.1	0.007	1.240	0.100	100%S
N85	294.17	335.4	0.003	1.395	0.089	100%S
N86	288.356	326.3	0.003	1.512	0.114	100%S
		With Primer Sika 55				
RH=50%						
N84P*	291.642	318	0.003	2.227	0.189	100%S
N85P*	294.17	280.9	0.005	1.514	0.114	100%S
N86P*	288.356	270.6	0.003	1.697	0.171	100%S
RH=65%						
N54P	281.776	389	0.003	0.913	0.079	100%S
N55P*	279.558	252.8	0.005	1.686	0.099	100%S
N56P*	288.795	483.8	0.005	1.677	0.124	100%S
RH=80%						
N64P	291.673	312.6	0.006	0.907	0.083	90%S+10%A
N65P*	289.44	303.2	0.009	1.697	0.129	98%S+2%A
N66P	288.04	319.9	0.004	1.380	0.147	100%S
RH=95%						
N74P	281.978	405.1	0.006	0.508	0.084	90%S+10%A
N75P*	292.584	439.2	0.009	2.135	0.171	95%S+5%A
N76P*	286.958	373.7	0.005	2.640	0.22	100%S

Table 17B. Adhesive Sika 32 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N54	281.776	332.8	0.013	0.725	0.042	100%S
N55	279.558	273.8	0.017	0.837	0.064	100%S
N56	288.795	317.7	0.003	1.147	0.112	100%S
Average		**308.1**	**0.011**	**0.903**	**0.073**	
RH=65%						
N64	291.673	394.6	0.002	1.032	0.114	100%S
N65	289.44	232.8	0.003	1.301	0.104	100%S
N66*	288.04	281.3	0.004	2.027	0.159	100%S
Average		**302.9**	**0.003**	**1.453**	**0.126**	
RH=80%						
N74	281.978	409.5	0.005	0.473	0.045	100%S
N75*	292.584	340.1	0.007	3.947	0.239	100%S
N76	286.958	394.5	0.005	0.451	0.046	95%S+5%A
Average		**381.4**	**0.006**	**1.624**	**0.110**	
RH=95%						
N84	291.642	330.1	0.007	1.240	0.100	100%S
N85	294.17	335.4	0.003	1.395	0.089	100%S
N86	288.356	326.3	0.003	1.512	0.114	100%S
Average		**330.6**	**0.004**	**1.382**	**0.101**	
		With Primer Sika 55				
RH=50%						
N84P*	291.642	318	0.003	2.227	0.189	100%S
N85P*	294.17	280.9	0.005	1.514	0.114	100%S
N86P*	288.356	270.6	0.003	1.697	0.171	100%S
Average		**289.8**	**0.004**	**1.813**	**0.158**	
RH=65%						
N54P	281.776	389	0.003	0.913	0.079	100%S
N55P*	279.558	252.8	0.005	1.686	0.099	100%S
N56P*	288.795	483.8	0.005	1.677	0.124	100%S
Average		**375.2**	**0.004**	**1.425**	**0.101**	
RH=80%						
N64P	291.673	312.6	0.006	0.907	0.083	90%S+10%A
N65P*	289.44	303.2	0.009	1.697	0.129	98%S+2%A
N66P	288.04	319.9	0.004	1.380	0.147	100%S
Average		**311.9**	**0.006**	**1.328**	**0.120**	
RH=95%						
N74P	281.978	405.1	0.006	0.508	0.084	90%S+10%A
N75P*	292.584	439.2	0.009	2.135	0.171	95%S+5%A
N76P*	286.958	373.7	0.005	2.640	0.220	100%S
Average		**406.0**	**0.007**	**1.761**	**0.158**	

Table 17C. Adhesive Sika 32 at Temperature 85°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
Without Primer				
RH%				
50	308.1	0.011	0.903	0.073
65	302.9	0.003	1.453	0.126
80	381.4	0.006	1.624	0.110
95	330.6	0.004	1.382	0.101
With Primer Sika 55				
RH%				
50	289.8	0.004	1.813	0.158
65	375.2	0.004	1.425	0.101
80	311.9	0.006	1.328	0.120
95	406	0.007	1.761	0.158

Data rearranged for plotting

RH%	No Primer	With Primer
50	308.1	289.8
65	302.9	375.2
80	381.4	311.9
95	330.6	406

Table 18. Adhesive Sika 32 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50%		Without Primer				
N94*	280.561	322.5	0.004	1.715	0.161	100%S
N95	283.215	300.9	0.002	0.445	0.034	100%S
N96	279.572	302	0.004	0.423	0.049	100%S
		With Primer Sika 55				
N94P	280.561	341.6	0.005	0.440	0.040	100%S
N95P*	283.215	319.5	0.004	2.075	0.214	100%S
N96P	279.572	348.7	0.003	0.489	0.066	100%S
RH=65%		Without Primer				
N104	301.486	403.9	0.003	0.725	0.09	100%S
N105*	289.653	276.9	0.004	3.11	0.245	100%S
N106	298.328	329.1	0.010	0.982	0.114	98%S+2%A
		With Primer Sika 55				
N104P	301.486	382	0.005	0.732	0.085	100%S
N105P	289.653	313.6	0.005	0.750	0.081	100%S
N106P	298.328	305.8	0.006	0.565	0.054	98%S+2%A
RH=80%		Without Primer				
N114	292.419	315.2	0.006	1.230	0.163	100%S
N115	297.12	294.9	0.004	0.250	0.034	100%S(thin lyr)
N116	305.989	259.3	0.009	0.252	0.018	100%S(thin lyr)
		With Primer Sika 55				
N114P	292.419	288.2	0.008	0.325	0.031	50%S+50%A
N115P	297.12	331.5	0.008	1.468	0.149	100%S
N116P	305.989	445.9	0.006	0.402	0.073	100%S(thin lyr)
RH=95%		Without Primer				
N124 SL	307.822	63.03	0.020	0.091	0.018	1%S+99%A
N125 SL	289.64	48.97	0.017	0.04	0.012	100%C
N126	305.451	122.7	0.003	0.086	0.038	5%S+95%A
		With Primer Sika 55				
N124PX	307.822	0	0.012	0.100	0.020	100%A
N125P	289.64	86.07	0.027	0.141	0.045	1%S+99%A
N126P	305.451	357.9	0.004	0.35	0.065	90%S+10%A

Table 18A. Adhesive Sika 32 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N94*	280.561	322.5	0.004	1.715	0.161	100%S
N95	283.215	300.9	0.002	0.445	0.034	100%S
N96	279.572	302	0.004	0.423	0.049	100%S
RH=65%						
N104	301.486	403.9	0.003	0.725	0.09	100%S
N105*	289.653	276.9	0.004	3.11	0.245	100%S
N106	298.328	329.1	0.010	0.982	0.114	98%S+2%A
RH=80%						
N114	292.419	315.2	0.006	1.230	0.163	100%S
N115	297.12	294.9	0.004	0.250	0.034	100%S(thin lyr)
N116	305.989	259.3	0.009	0.252	0.018	100%S(thin lyr)
RH=95%						
N124 SL	307.822	63.03	0.020	0.091	0.018	1%S+99%A
N125 SL	289.64	48.97	0.017	0.04	0.012	100%C
N126	305.451	122.7	0.003	0.086	0.038	5%S+95%A
		With Primer Sika 55				
RH=50%						
N94P	280.561	341.6	0.005	0.440	0.040	100%S
N95P*	283.215	319.5	0.004	2.075	0.214	100%S
N96P	279.572	348.7	0.003	0.489	0.066	100%S
RH=65%						
N104P	301.486	382	0.005	0.732	0.085	100%S
N105P	289.653	313.6	0.005	0.750	0.081	100%S
N106P	298.328	305.8	0.006	0.565	0.054	98%S+2%A
RH=80%						
N114P	292.419	288.2	0.008	0.325	0.031	50%S+50%A
N115P	297.12	331.5	0.008	1.468	0.149	100%S
N116P	305.989	445.9	0.006	0.402	0.073	100%S(thin lyr)
RH=95%						
N124PX	307.822	0	0.012	0.100	0.020	100%A
N125P	289.64	86.07	0.027	0.141	0.045	1%S+99%A
N126P	305.451	357.9	0.004	0.35	0.065	90%S+10%A

Table 18B. Adhesive Sika 32 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Without Primer						
RH=50%						
N94*	280.561	322.5	0.004	1.715	0.161	100%S
N95	283.215	300.9	0.002	0.445	0.034	100%S
N96	279.572	302	0.004	0.423	0.049	100%S
Average		**308.5**	**0.003**	**0.861**	**0.081**	
RH=65%						
N104	301.486	403.9	0.003	0.725	0.09	100%S
N105*	289.653	276.9	0.004	3.11	0.245	100%S
N106	298.328	329.1	0.010	0.982	0.114	98%S+2%A
Average		**336.6**	**0.006**	**1.606**	**0.150**	
RH=80%						
N114	292.419	315.2	0.006	1.230	0.163	100%S
N115	297.12	294.9	0.004	0.250	0.034	100%S(thin lyr)
N116	305.989	259.3	0.009	0.252	0.018	100%S(thin lyr)
Average		**289.8**	**0.006**	**0.577**	**0.072**	
RH=95%						
N124 SL	307.822	63.03X	0.020	0.091	0.018	1%S+99%A
N125 SL	289.64	48.97X	0.017	0.04	0.012	100%C
N126	305.451	122.7	0.003	0.086	0.038	5%S+95%A
Average		**122.7**	**0.013**	**0.072**	**0.023**	
With Primer Sika 55						
RH=50%						
N94P	280.561	341.6	0.005	0.440	0.040	100%S
N95P*	283.215	319.5	0.004	2.075	0.214	100%S
N96P	279.572	348.7	0.003	0.489	0.066	100%S
Average		**336.6**	**0.004**	**1.001**	**0.107**	
RH=65%						
N104P	301.486	382	0.005	0.732	0.085	100%S
N105P	289.653	313.6	0.005	0.750	0.081	100%S
N106P	298.328	305.8	0.006	0.565	0.054	98%S+2%A
Average		**333.8**	**0.005**	**0.682**	**0.073**	
RH=80%						
N114P	292.419	288.2	0.008	0.325	0.031	50%S+50%A
N115P	297.12	331.5	0.008	1.468	0.149	100%S
N116P	305.989	445.9	0.006	0.402	0.073	100%S(thin lyr)
Average		**355.2**	**0.007**	**0.732**	**0.084**	
RH=95%						
N124PX	307.822	0	0.012	0.100	0.020	100%A
N125P	289.64	86.07	0.027	0.141	0.045	1%S+99%A
N126P	305.451	357.9	0.004	0.35	0.065	90%S+10%A
Average		**222.0**	**0.014**	**0.197**	**0.043**	

Table 18C. Adhesive Sika 32 at Temperature 100°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
Without Primer				
RH%				
50	308.5	0.003	0.861	0.081
65	336.6	0.006	1.606	0.15
80	289.8	0.006	0.577	0.072
95	122.7	0.013	0.072	0.023
With Primer Sika 55				
RH%				
50	336.6	0.004	1.001	0.107
65	333.8	0.005	0.682	0.073
80	355.2	0.007	0.732	0.084
95	222	0.014	0.197	0.043

Data rearranged for plotting

RH%	No Primer	With Primer
50	308.5	336.6
65	336.6	333.8
80	289.8	355.2
95	122.7	222

Table 19. Adhesive Madewell 1312 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50%		Without Primer				
N17	281.962	212.6	0.005	0.609	0.104	100%S
N18*	291.696	315.2	0.001	1.746	0.159	100%S
N19	281.738	243.2	0.005	0.891	0.146	100%S
		With Primer Madewell 927				
N17P	281.962	244.2	0.001	1.937	0.159	100%S
N18P*	291.696	329.4	0.008	2.097	0.183	100%S
N19P	281.738	183.4	0.002	0.982	0.119	100%S
RH=65%		Without Primer				
N27-SL	286.433	149.4	0.005	0.497	0.091	90%S+10%A
N28	265.607	161.3	0.012	1.011	0.164	100%S
N29	276.982	267.2	0.006	1.114	0.168	100%S
		With Primer Madewell 927				
N27P	286.433	306	0.006	1.448	0.129	100%S
N28P*	265.607	167.3	0.005	1.85	0.161	100%S
N29P*	276.982	233.6	0.007	2.103	0.159	100%S
RH=80%		Without Primer				
N37	280.439	184.3	0.005	0.731	0.088	100%S
N38	288.469	136	0.002	0.374	0.064	98%S+2%A
N39	270.004	128.5	0.002	0.845	0.151	95%S+5%A
		With Primer Madewell 927				
N37P	280.439	261.2	0.004	0.876	0.109	100%S
N38P	288.469	298.5	0.004	0.809	0.084	100%S
N39P	270.004	194.2	0.004	1.221	0.117	100%S
RH=95%		Without Primer				
N47	278.662	200.7	0.009	0.892	0.118	96%S+4%A
N48	289.921	315.4	0.009	0.838	0.089	100%S
N49	281.559	229.8	0.005	1.422	0.169	100%S
		With Primer Madewell 927				
N47P	278.662	304.2	0.005	1.272	0.132	100%S
N48P*	289.921	369	0.004	1.924	0.139	100%S
N49P	281.559	264.2	0.004	1.189	0.096	100%S

Table 19A. Adhesive Madewell 1312 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N17	281.962	212.6	0.005	0.609	0.104	100%S
N18*	291.696	315.2	0.001	1.746	0.159	100%S
N19	281.738	243.2	0.005	0.891	0.146	100%S
RH=65%						
N27-SL	286.433	149.4	0.005	0.497	0.091	90%S+10%A
N28	265.607	161.3	0.012	1.011	0.164	100%S
N29	276.982	267.2	0.006	1.114	0.168	100%S
RH=80%						
N37	280.439	184.3	0.005	0.731	0.088	100%S
N38	288.469	136	0.002	0.374	0.064	98%S+2%A
N39	270.004	128.5	0.002	0.845	0.151	95%S+5%A
RH=95%						
N47	278.662	200.7	0.009	0.892	0.118	96%S+4%A
N48	289.921	315.4	0.009	0.838	0.089	100%S
N49	281.559	229.8	0.005	1.422	0.169	100%S
		With Primer Madewell 927				
RH=50%						
N17P	281.962	244.2	0.001	1.937	0.159	100%S
N18P*	291.696	329.4	0.008	2.097	0.183	100%S
N19P	281.738	183.4	0.002	0.982	0.119	100%S
RH=65%						
N27P	286.433	306	0.006	1.448	0.129	100%S
N28P*	265.607	167.3	0.005	1.85	0.161	100%S
N29P*	276.982	233.6	0.007	2.103	0.159	100%S
RH=80%						
N37P	280.439	261.2	0.004	0.876	0.109	100%S
N38P	288.469	298.5	0.004	0.809	0.084	100%S
N39P	270.004	194.2	0.004	1.221	0.117	100%S
RH=95%						
N47P	278.662	304.2	0.005	1.272	0.132	100%S
N48P*	289.921	369	0.004	1.924	0.139	100%S
N49P	281.559	264.2	0.004	1.189	0.096	100%S

Table 19B. Adhesive Madewell 1312 at Temperature 70°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N17	281.962	212.6	0.005	0.609	0.104	100%S
N18*	291.696	315.2	0.001	1.746	0.159	100%S
N19	281.738	243.2	0.005	0.891	0.146	100%S
Average		**257.0**	**0.004**	**1.082**	**0.136**	
RH=65%						
N27-SL	286.433	149.4	0.005	0.497	0.091	90%S+10%A
N28	265.607	161.3	0.012	1.011	0.164	100%S
N29	276.982	267.2	0.006	1.114	0.168	100%S
Average		**192.6**	**0.008**	**0.874**	**0.141**	
RH=80%						
N37	280.439	184.3	0.005	0.731	0.088	100%S
N38	288.469	136	0.002	0.374	0.064	98%S+2%A
N39	270.004	128.5	0.002	0.845	0.151	95%S+5%A
Average		**149.6**	**0.003**	**0.650**	**0.101**	
RH=95%						
N47	278.662	200.7	0.009	0.892	0.118	96%S+4%A
N48	289.921	315.4	0.009	0.838	0.089	100%S
N49	281.559	229.8	0.005	1.422	0.169	100%S
Average		**248.6**	**0.008**	**1.051**	**0.125**	
		With Primer Madewell 927				
RH=50%						
N17P	281.962	244.2	0.001	1.937	0.159	100%S
N18P*	291.696	329.4	0.008	2.097	0.183	100%S
N19P	281.738	183.4	0.002	0.982	0.119	100%S
Average		**252.3**	**0.004**	**1.672**	**0.154**	
RH=65%						
N27P	286.433	306	0.006	1.448	0.129	100%S
N28P*	265.607	167.3	0.005	1.85	0.161	100%S
N29P*	276.982	233.6	0.007	2.103	0.159	100%S
Average		**235.6**	**0.006**	**1.800**	**0.150**	
RH=80%						
N37P	280.439	261.2	0.004	0.876	0.109	100%S
N38P	288.469	298.5	0.004	0.809	0.084	100%S
N39P	270.004	194.2	0.004	1.221	0.117	100%S
Average		**251.3**	**0.004**	**0.969**	**0.103**	
RH=95%						
N47P	278.662	304.2	0.005	1.272	0.132	100%S
N48P*	289.921	369	0.004	1.924	0.139	100%S
N49P	281.559	264.2	0.004	1.189	0.096	100%S
Average		**312.5**	**0.004**	**1.462**	**0.122**	

Table 19C. Adhesive Madewell 1312 at Temperature 70°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
Without Primer				
RH%				
50	257	0.004	1.082	0.136
65	192.6	0.008	0.874	0.141
80	149.6	0.003	0.65	0.101
95	248.6	0.008	1.051	0.125
With Primer Madewell 927				
RH%				
50	252.3	0.004	1.672	0.154
65	235.6	0.006	1.8	0.15
80	251.3	0.004	0.969	0.103
95	312.5	0.004	1.462	0.122

Data rearranged for plotting

RH%	No Primer	With Primer
50	257	252.3
65	192.6	235.6
80	149.6	251.3
95	248.6	312.5

Table 20. Adhesive Madewell 1312 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50%		Without Primer				
N57	287.163	406.7	0.004	0.561	0.062	98%S+2%A
N58	290.875	291.5	0.005	0.525	0.067	100%S
N59	288.471	170	0.005	0.396	0.043	100%S
		With Primer Madewell 927				
N57PX	287.163	0	0.006	0.085	0.090	100%A
N58P	290.875	458.3	0.004	0.633	0.075	98%S+2%A
N59P	288.471	330.3	0.003	1.270	0.123	100%S
RH=65%		Without Primer				
N67*	289.809	277.9	0.011	2.105	0.207	100%S
N68 SL	286.662	253.7	0.009	0.411	0.061	75%S+25%A
N69	292.428	223.2	0.004	0.922	0.124	100%S
		With Primer Madewell 927				
N67P*	289.809	256	0.002	1.731	0.144	100%S
N68P	286.662	259.1	0.008	0.747	0.083	100%S
N69P	292.428	329.1	0.007	0.908	0.094	100%S
RH=80%		Without Primer				
N77	285.693	381.5	0.005	0.798	0.107	100%S
N78*	292.739	320.8	0.003	1.557	0.112	100%S
N79	283.421	375.4	0.007	0.67	0.094	100%S
		With Primer Madewell 927				
N77P	285.693	438.3	0.008	0.471	0.059	100%S
N78P	292.739	258.3	0.003	0.843	0.1	100%S
N79P	283.421	393.6	0.003	0.519	0.065	100%S
RH=95%		Without Primer				
N87 SL	290.119	231.5	0.005	1.105	0.14	100%S
N88	292.453	231.8	0.007	0.815	0.104	95%S+5%A
N89 SL	291.94	307.4	0.003	1.07	0.127	100%S
		With Primer Madewell 927				
N87P	290.119	332.1	0.004	1.41	0.126	100%S
N88P	292.453	337.6	0.009	1	0.114	100%S
N89P*	291.94	370.6	0.004	2.72	0.199	100%S

Table 20A. Adhesive Madewell 1312 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N57	287.163	406.7	0.004	0.561	0.062	98%S+2%A
N58	290.875	291.5	0.005	0.525	0.067	100%S
N59	288.471	170	0.005	0.396	0.043	100%S
RH=65%						
N67*	289.809	277.9	0.011	2.105	0.207	100%S
N68 SL	286.662	253.7	0.009	0.411	0.061	75%S+25%A
N69	292.428	223.2	0.004	0.922	0.124	100%S
RH=80%						
N77	285.693	381.5	0.005	0.798	0.107	100%S
N78*	292.739	320.8	0.003	1.557	0.112	100%S
N79	283.421	375.4	0.007	0.670	0.094	100%S
RH=95%						
N87 SL	290.119	231.5	0.005	1.105	0.140	100%S
N88	292.453	231.8	0.007	0.815	0.104	95%S+5%A
N89 SL	291.94	307.4	0.003	1.070	0.127	100%S
		With Primer Madewell 927				
RH=50%						
N87P	290.119	332.1	0.004	1.410	0.126	100%S
N88P	292.453	337.6	0.009	1.000	0.114	100%S
N89P*	291.94	370.6	0.004	2.720	0.199	100%S
RH=65%						
N57PX	287.163	0	0.006	0.085	0.090	100%A
N58P	290.875	458.3	0.004	0.633	0.075	98%S+2%A
N59P	288.471	330.3	0.003	1.270	0.123	100%S
RH=80%						
N67P*	289.809	256	0.002	1.731	0.144	100%S
N68P	286.662	259.1	0.008	0.747	0.083	100%S
N69P	292.428	329.1	0.007	0.908	0.094	100%S
RH=95%						
N77P	285.693	438.3	0.008	0.471	0.059	100%S
N78P	292.739	258.3	0.003	0.843	0.100	100%S
N79P	283.421	393.6	0.003	0.519	0.065	100%S

Table 20B. Adhesive Madewell 1312 at Temperature 85°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N57	287.163	406.7	0.004	0.561	0.062	98%S+2%A
N58	290.875	291.5	0.005	0.525	0.067	100%S
N59	288.471	170	0.005	0.396	0.043	100%S
Average		**289.4**	**0.005**	**0.494**	**0.057**	
RH=65%						
N67*	289.809	277.9	0.011	2.105	0.207	100%S
N68 SL	286.662	253.7	0.009	0.411	0.061	75%S+25%A
N69	292.428	223.2	0.004	0.922	0.124	100%S
Average		**251.6**	**0.008**	**1.146**	**0.131**	
RH=80%						
N77	285.693	381.5	0.005	0.798	0.107	100%S
N78*	292.739	320.8	0.003	1.557	0.112	100%S
N79	283.421	375.4	0.007	0.670	0.094	100%S
Average		**359.2**	**0.005**	**1.008**	**0.104**	
RH=95%						
N87 SL	290.119	231.5	0.005	1.105	0.140	100%S
N88	292.453	231.8	0.007	0.815	0.104	95%S+5%A
N89 SL	291.94	307.4	0.003	1.070	0.127	100%S
Average		**256.9**	**0.005**	**0.997**	**0.124**	
		With Primer Madewell 927				
RH=50%						
N87P	290.119	332.1	0.004	1.410	0.126	100%S
N88P	292.453	337.6	0.009	1.000	0.114	100%S
N89P*	291.94	370.6	0.004	2.720	0.199	100%S
Average		**346.8**	**0.006**	**1.710**	**0.146**	
RH=65%						
N57PX	287.163	0	0.006	0.085	0.090	100%A
N58P	290.875	458.3	0.004	0.633	0.075	98%S+2%A
N59P	288.471	330.3	0.003	1.270	0.123	100%S
Average		**394.3**	**0.004**	**0.663**	**0.096**	
RH=80%						
N67P*	289.809	256	0.002	1.731	0.144	100%S
N68P	286.662	259.1	0.008	0.747	0.083	100%S
N69P	292.428	329.1	0.007	0.908	0.094	100%S
Average		**281.4**	**0.006**	**1.129**	**0.107**	
RH=95%						
N77P	285.693	438.3	0.008	0.471	0.059	100%S
N78P	292.739	258.3	0.003	0.843	0.100	100%S
N79P	283.421	393.6	0.003	0.519	0.065	100%S
Average		**363.4**	**0.005**	**0.611**	**0.075**	

Table 20C. Adhesive Madewell 1312 at Temperature 85°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
Without Primer				
RH%				
50	289.4	0.005	0.494	0.057
65	251.6	0.008	1.146	0.131
80	359.2	0.005	1.008	0.104
95	256.9	0.005	0.997	0.124
With Primer Madewell 927				
RH%				
50	346.8	0.006	1.71	0.146
65	394.3	0.004	0.663	0.096
80	281.4	0.006	1.129	0.107
95	363.4	0.005	0.611	0.075

Data rearranged for plotting

RH%	No Primer	With Primer
50	289.4	346.8
65	251.6	394.3
80	359.2	281.4
95	256.9	363.4

Table 21. Adhesive Madewell 1312 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
RH=50%		Without Primer				
N97R	280.561	352.000	0.005	0.497	0.070	98%S+2%A
N98R	283.215	277.000	0.004	0.509	0.085	100%S
N99R	279.572	453.000	0.002	0.468	0.060	100%S
		With Primer Madewell 927				
N97PR	286.211	428.200	0.003	0.969	0.135	100%S
N98PR	281.546	468.000	0.009	0.642	0.095	100%S
N99PR	290.306	412.800	0.003	0.236	0.057	98%S+2%A
RH=65%		Without Primer				
N107	287.55	243.8	0.003	0.330	0.069	95%S+5%A
N108*	285.745	320.4	0.004	1.565	0.168	100%S
N109	287.488	342.7	0.003	0.552	0.072	100%S
		With Primer Madewell 927				
N107P	287.55	292.2	0.03	0.530	0.067	95%S+5%A
N108P	285.745	312.5	0.002	0.270	0.090	40%S+60%A
N109P	287.488	327.9	0.004	0.619	0.075	100%S
RH=80%		Without Primer				
N117	306.328	429.4	0.004	0.345	0.087	75%S+25%A
N118 SL	309.997	265.1	0.005	0.785	0.126	100%S
N119 SL	287.058	194.5	0.003	0.955	0.124	100%S
		With Primer Madewell 927				
N117P	306.328	287.1	0.007	1.117	0.133	100%S
N118P	309.997	371.9	0.008	0.255	0.030	100%S(thin lyr)
N119P	287.058	350.3	0.003	0.630	0.074	98%S+2%A
Rh=95%		Without Primer				
N127X	290.985	0	0.003	0.002	0.004	100%A
N128 SL	323.841	111.8	0.011	0.098	0.040	5%S+95%A
N129 SL	298.946	125.2	0.01	0.068	0.068	2%S+98%A
		With Primer Madewell 927				
N127P*	290.985	209	0.003	1.608	0.273	100%S
N128P	323.841	364.2	0.009	0.295	0.081	20%S+80%A
N129P	298.946	359.3	0.017	0.053	0.053	50%S+50%A

Table 21A. Adhesive Madewell 1312 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
		Without Primer				
RH=50%						
N97R	280.561	352.0	0.005	0.497	0.070	98%S+2%A
N98R	283.215	277.0	0.004	0.509	0.085	100%S
N99R	279.572	453.0	0.002	0.468	0.060	100%S
RH=65%						
N107	287.55	243.8	0.003	0.330	0.069	95%S+5%A
N108*	285.745	320.4	0.004	1.565	0.168	100%S
N109	287.488	342.7	0.003	0.552	0.072	100%S
RH=80%						
N117	306.328	429.4	0.004	0.345	0.087	75%S+25%A
N118 SL	309.997	265.1	0.005	0.785	0.126	100%S
N119 SL	287.058	194.5	0.003	0.955	0.124	100%S
RH=95%						
N127X	290.985	0	0.003	0.002	0.004	100%A
N128 SL	323.841	111.8	0.011	0.098	0.040	5%S+95%A
N129 SL	298.946	125.2	0.01	0.068	0.068	2%S+98%A
		With Primer Madewell 927				
RH=50%						
N97PR	286.211	428.2	0.003	0.969	0.135	100%S
N98PR	281.546	468.0	0.009	0.642	0.095	100%S
N99PR	290.306	412.8	0.003	0.236	0.057	98%S+2%A
RH=65%						
N107P	287.55	292.2	0.03	0.530	0.067	95%S+5%A
N108P	285.745	312.5	0.002	0.270	0.090	40%S+60%A
N109P	287.488	327.9	0.004	0.619	0.075	100%S
RH=80%						
N117P	306.328	287.1	0.007	1.117	0.133	100%S
N118P	309.997	371.9	0.008	0.255	0.030	100%S(thin lyr)
N119P	287.058	350.3	0.003	0.630	0.074	98%S+2%A
RH=95%						
N127P*	290.985	209	0.003	1.608	0.273	100%S
N128P	323.841	364.2	0.009	0.295	0.081	20%S+80%A
N129P	298.946	359.3	0.017	0.053	0.053	50%S+50%A

Table 21B. Adhesive Madewell 1312 at Temperature 100°F.

TEST	Mass of Mortar Cube grams	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch	Type of Failure S=substrate A=adhesive C=cohesive
Without Primer						
RH=50%						
N97R	280.561	352.0	0.005	0.497	0.070	98%S+2%A
N98R	283.215	277.0	0.004	0.509	0.085	100%S
N99R	279.572	453.0	0.002	0.468	0.060	100%S
Average		**360.7**	**0.004**	**0.491**	**0.072**	
RH=65%						
N107	287.55	243.8	0.003	0.330	0.069	95%S+5%A
N108*	285.745	320.4	0.004	1.565	0.168	100%S
N109	287.488	342.7	0.003	0.552	0.072	100%S
Average		**302.3**	**0.003**	**0.816**	**0.103**	
RH=80%						
N117	306.328	429.4	0.004	0.345	0.087	75%S+25%A
N118 SL	309.997	265.1	0.005	0.785	0.126	100%S
N119 SL	287.058	194.5	0.003	0.955	0.124	100%S
Average		**296.3**	**0.004**	**0.695**	**0.112**	
RH=95%						
N127X	290.985	0	0.003	0.002	0.004	100%A
N128 SL	323.841	111.8	0.011	0.098	0.040	5%S+95%A
N129 SL	298.946	125.2	0.01	0.068	0.068	2%S+98%A
Average		**118.5**	**0.008**	**0.056**	**0.037**	
With Primer Madewell 927						
RH=50%						
N97PR	286.211	428.2	0.003	0.969	0.135	100%S
N98PR	281.546	468.0	0.009	0.642	0.095	100%S
N99PR	290.306	412.8	0.003	0.236	0.057	98%S+2%A
Average		**436.3**	**0.005**	**0.616**	**0.096**	
RH=65%						
N107P	287.55	292.2	0.03	0.530	0.067	95%S+5%A
N108P	285.745	312.5	0.002	0.270	0.090	40%S+60%A
N109P	287.488	327.9	0.004	0.619	0.075	100%S
Average		**310.9**	**0.012**	**0.473**	**0.077**	
RH=80%						
N117P	306.328	287.1	0.007	1.117	0.133	100%S
N118P	309.997	371.9	0.008	0.255	0.030	100%S(thin lyr)
N119P	287.058	350.3	0.003	0.630	0.074	98%S+2%A
Average		**336.4**	**0.006**	**0.667**	**0.079**	
RH=95%						
N127P*	290.985	209	0.003	1.608	0.273	100%S
N128P	323.841	364.2	0.009	0.295	0.081	20%S+80%A
N129P	298.946	359.3	0.017	0.053	0.053	50%S+50%A
Average		**310.8**	**0.01**	**0.652**	**0.136**	

Table 21C. Adhesive Madewell 1312 at Temperature 100°F.

TEST	Peak Load to pull off dolly pounds	Adhesive Film Thickness inch	Pulled off Mass of Mortar Layer grams	Max Height of Mortar Layer inch
Without Primer				
RH%				
50	360.7	0.004	0.491	0.072
65	302.3	0.003	0.816	0.103
80	296.3	0.004	0.695	0.112
95	118.5	0.008	0.056	0.037
With Primer Madewell 927				
RH%				
50	436.3	0.005	0.616	0.096
65	310.9	0.012	0.473	0.077
80	336.4	0.006	0.667	0.079
95	310.8	0.010	0.652	0.136

Data rearranged for plotting

RH%	No Primer	With Primer
50	360.7	436.3
65	302.3	310.9
80	296.3	336.4
95	118.5	310.8

Table 22. Distribution of Types of Failures.

TEMPERATURE = 70 DEG F

RH%	Substrate 100%	Substrate 99%-80%	Substrate 79%-60%	Substrate 59%-1%	Adhesive 100%	Cohesive 100%	Total
50(Set1)	18	0	0	0	0	0	18
65(Set2)	12	5	0	1	0	0	18
80(Set3)	10	5	1	2	0	0	18
95(Set4)	11	3	0	4	0	0	18
Total A	51	13	1	7	0	0	72

TEMPERATURE = 85 DEG F

RH%	Substrate 100%	Substrate 99%-80%	Substrate 79%-60%	Substrate 59%-1%	Adhesive 100%	Cohesive 100%	Total
50(Set5)	9	6	2		1	0	18
65(Set6)	11	4	2	1	0	0	18
80(Set7)	11	5	0	2	0	0	18
95(Set8)	13	5	0	0	0	0	18
Total B	44	20	4	3	1	0	72

TEMPERATURE = 100 DEG F

RH%	Substrate 100%	Substrate 99%-80%	Substrate 79%-60%	Substrate 59%-1%	Adhesive 100%	Cohesive 100%	Total
50(Set9)	11	5	1	1	0	0	18
65(Set10)	8	7	2	1	0	0	18
80(Set11)	10	2	4	2	0	0	18
95(Set12)	3	3	1	8	2	1	18
Total C	32	17	8	12	2	1	72
A+B+C	127	50	13	22	3	1	216
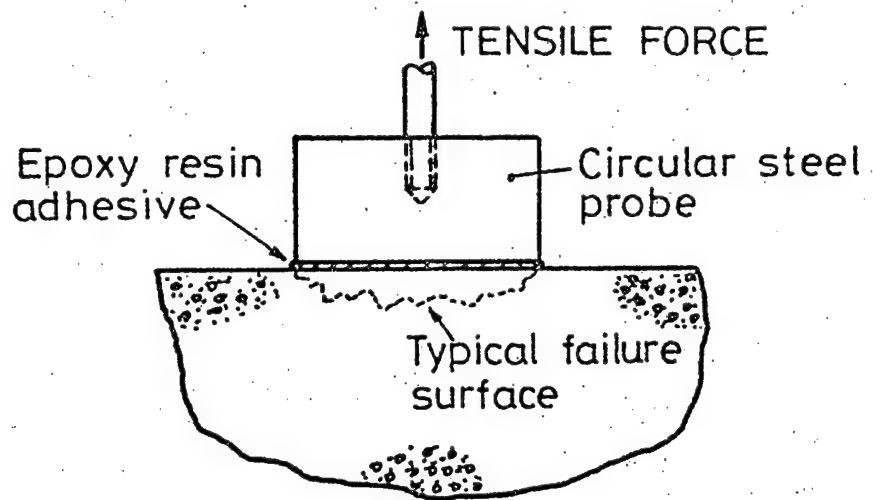
Arrangement for testing uncored specimens

Figure 1: Original Version of Pull-Off Test (after A. E. Long)
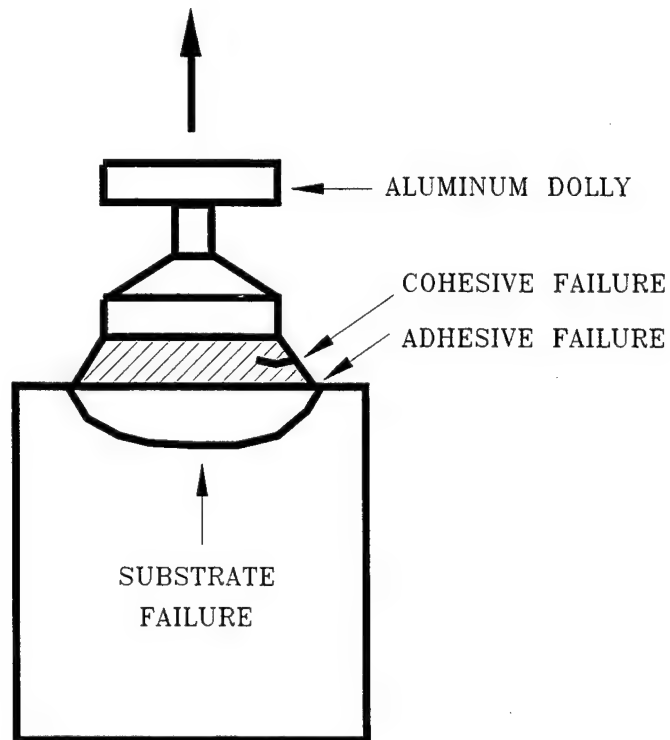
Figure 2: Schematic of Different Types of Failures
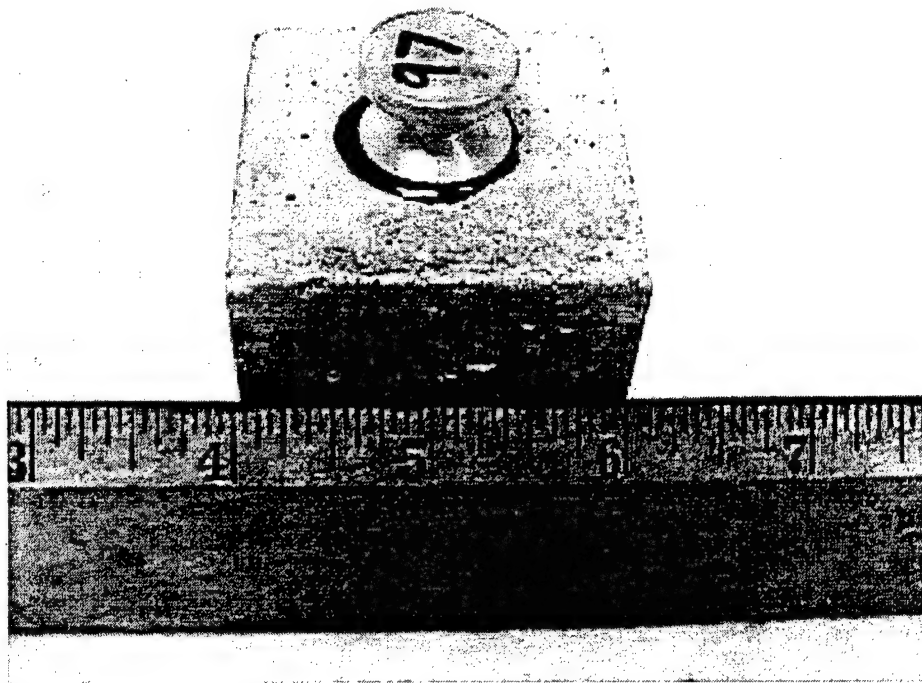
Figure 3: Photo of Dolly attached to Cement Mortar Cube showing Dimensions
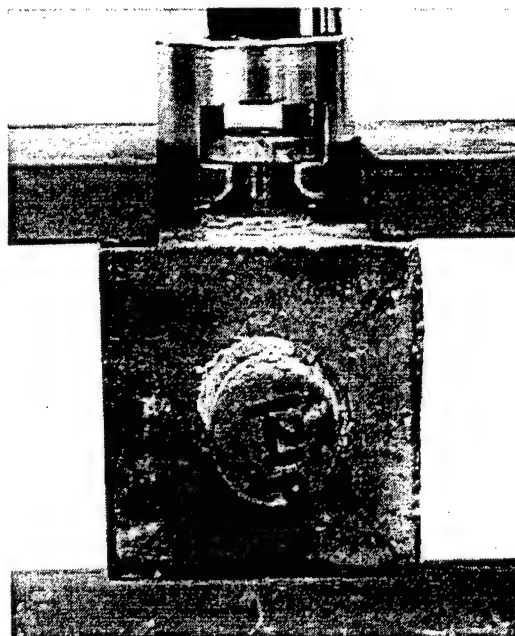
Figure 4: Special Fixture for Pull-Off Test with Instron Testing Machine
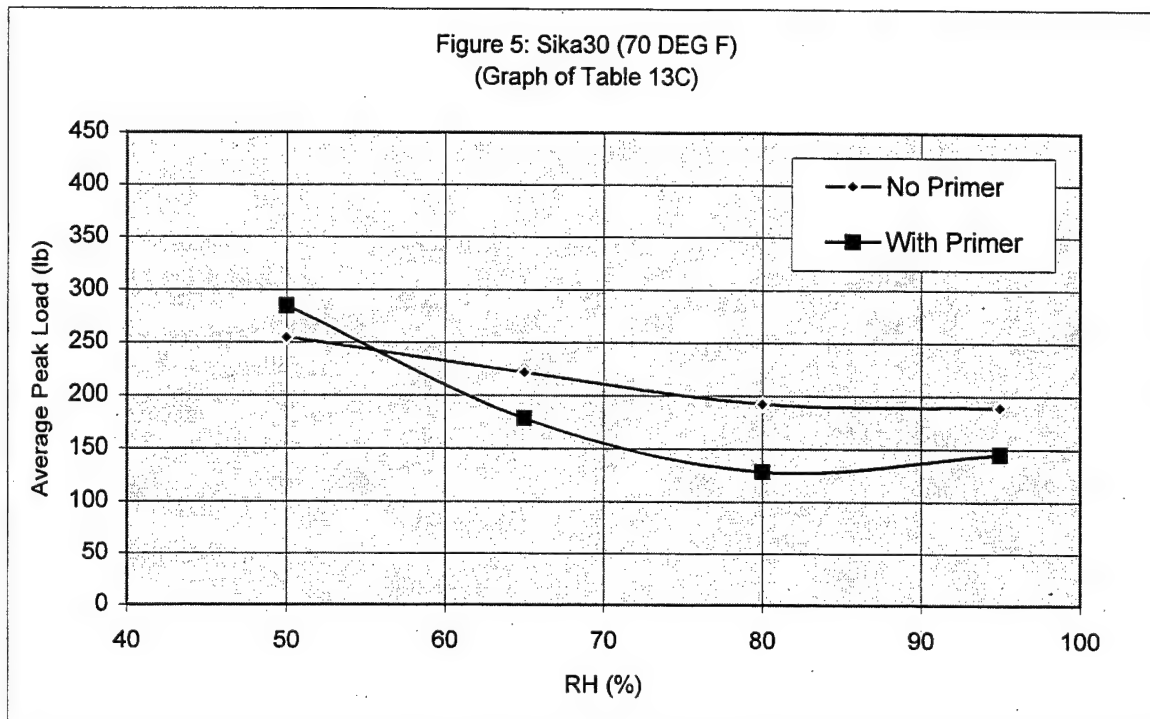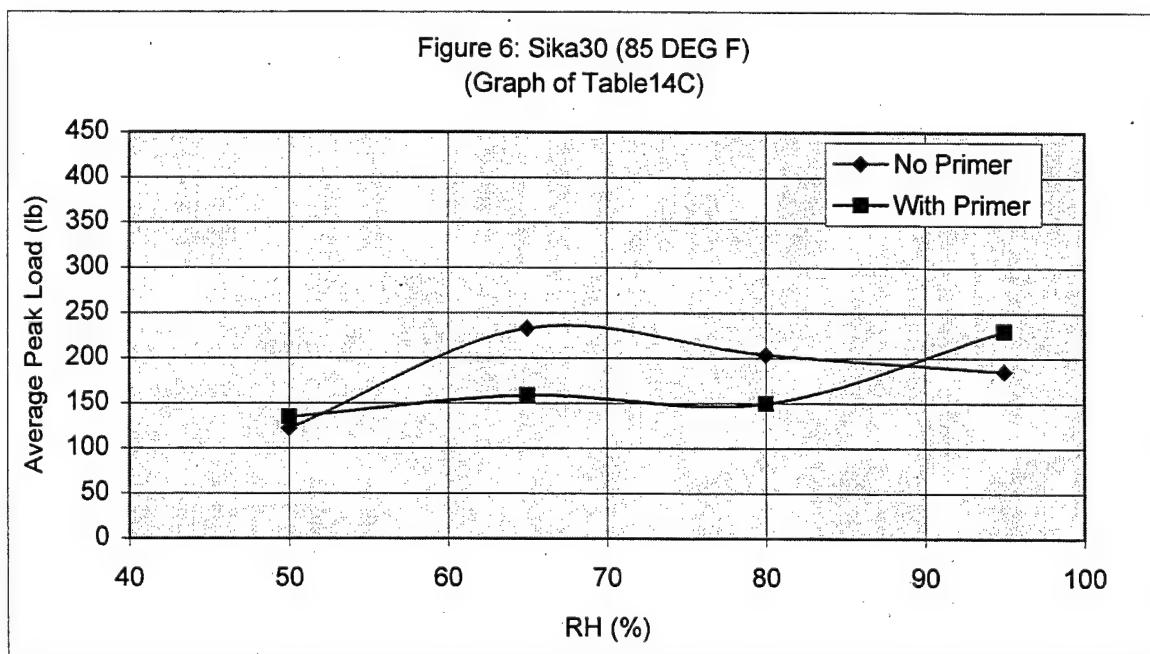
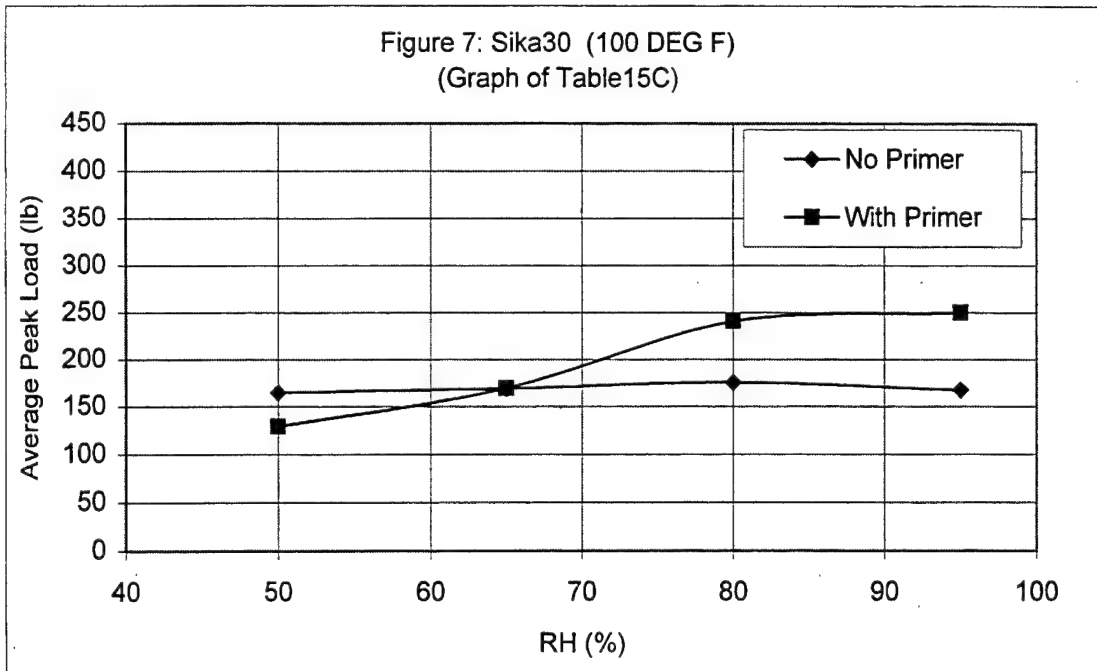Figure 5: Sika 30 at 70°F

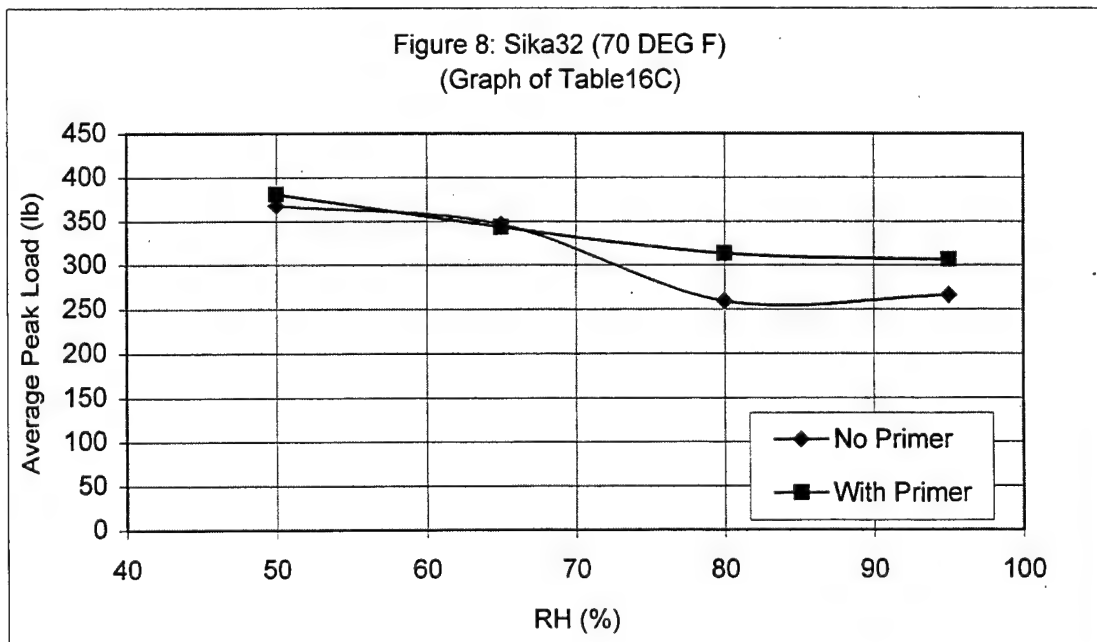Figure 6: Sika 30 at 85°F

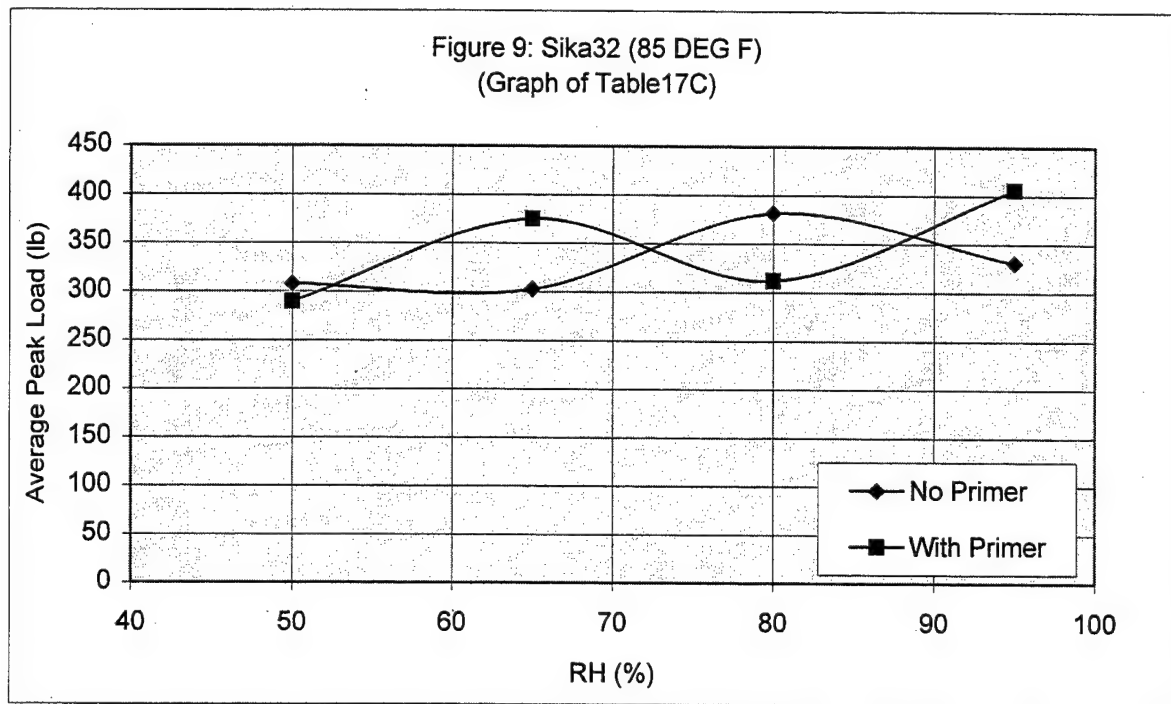Figure 7: Sika 30 at 100°F
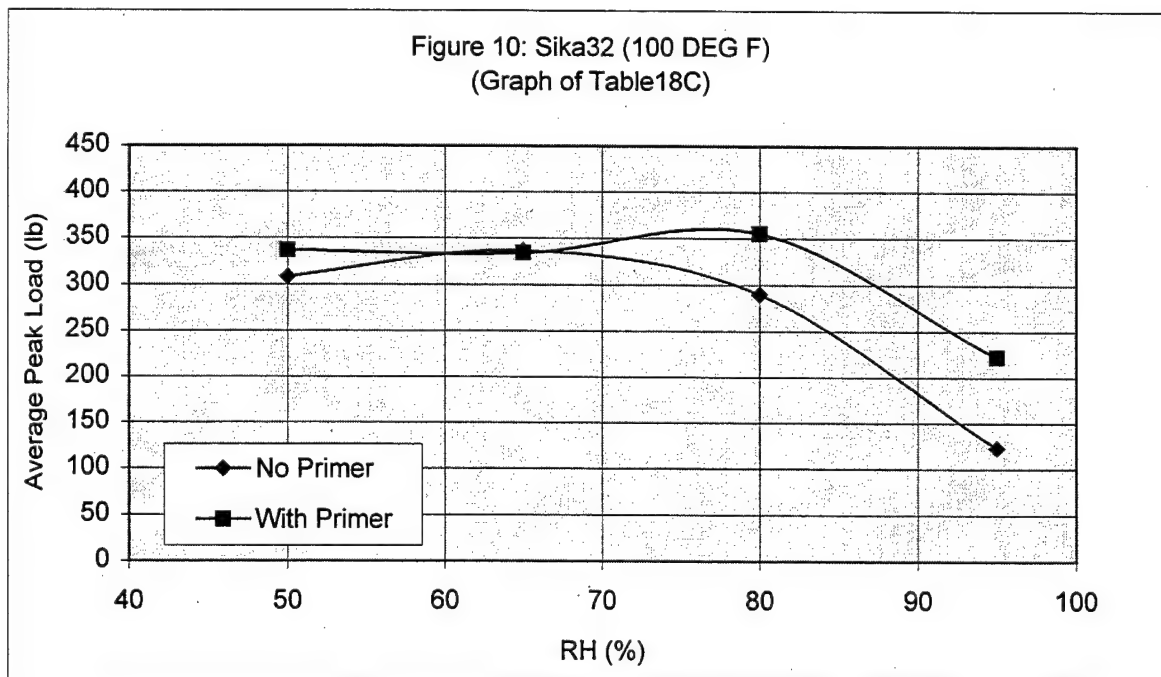

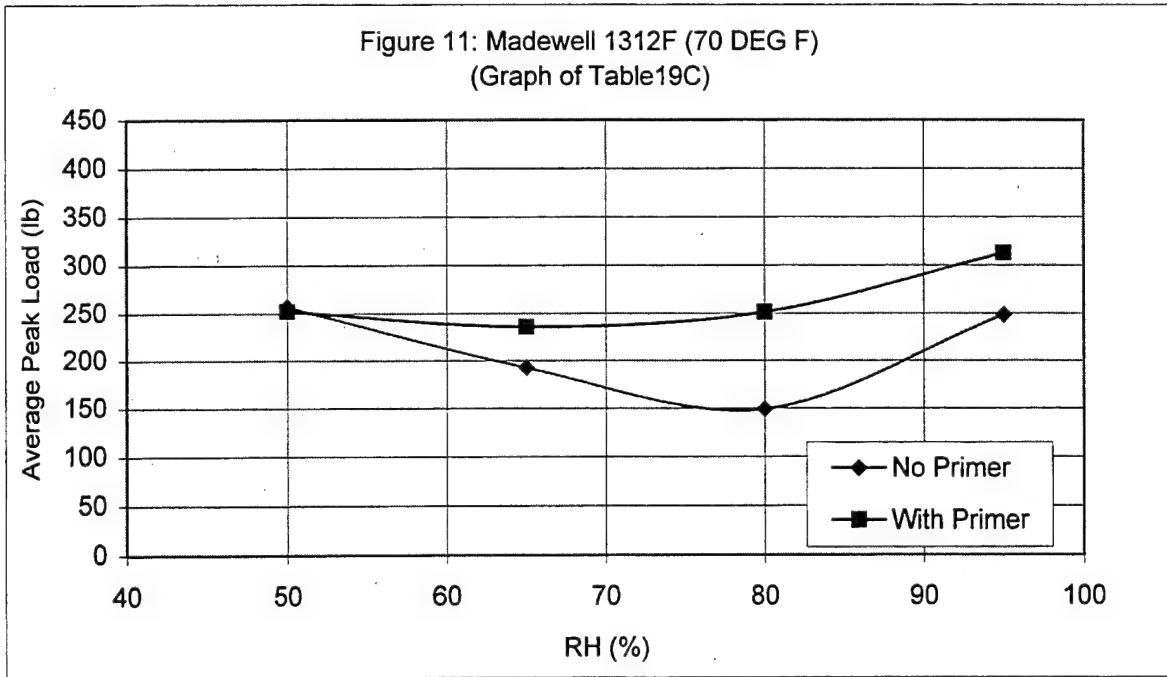Figure 8: Sika 32 at 70°F

Figure 9: Sika 32 at 85°F

Figure 10: Sika 32 at 100°F
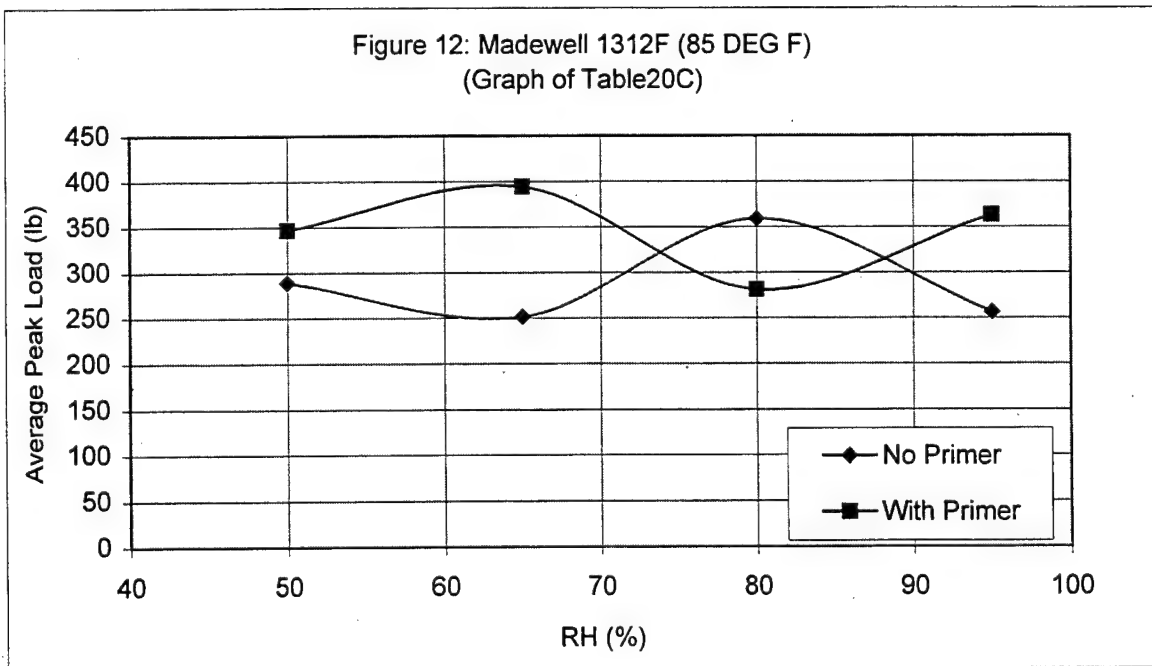
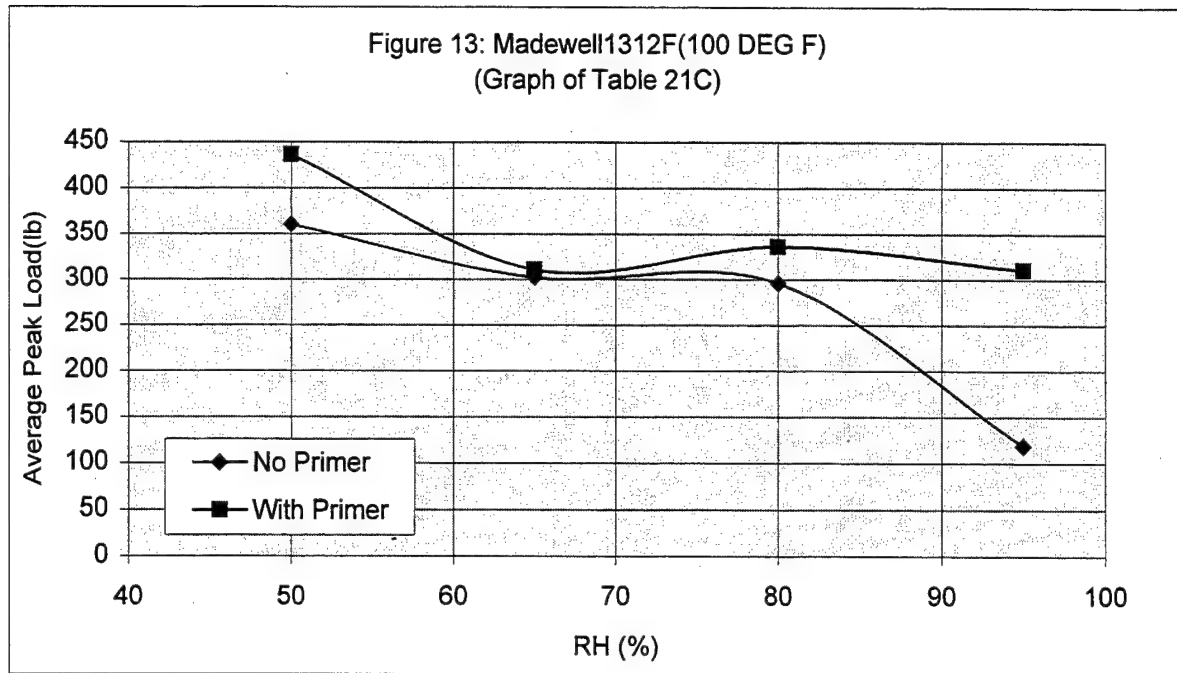Figure 11: Madewell 1312 at 70°F

Figure 12: Madewell 1312 at 85°F
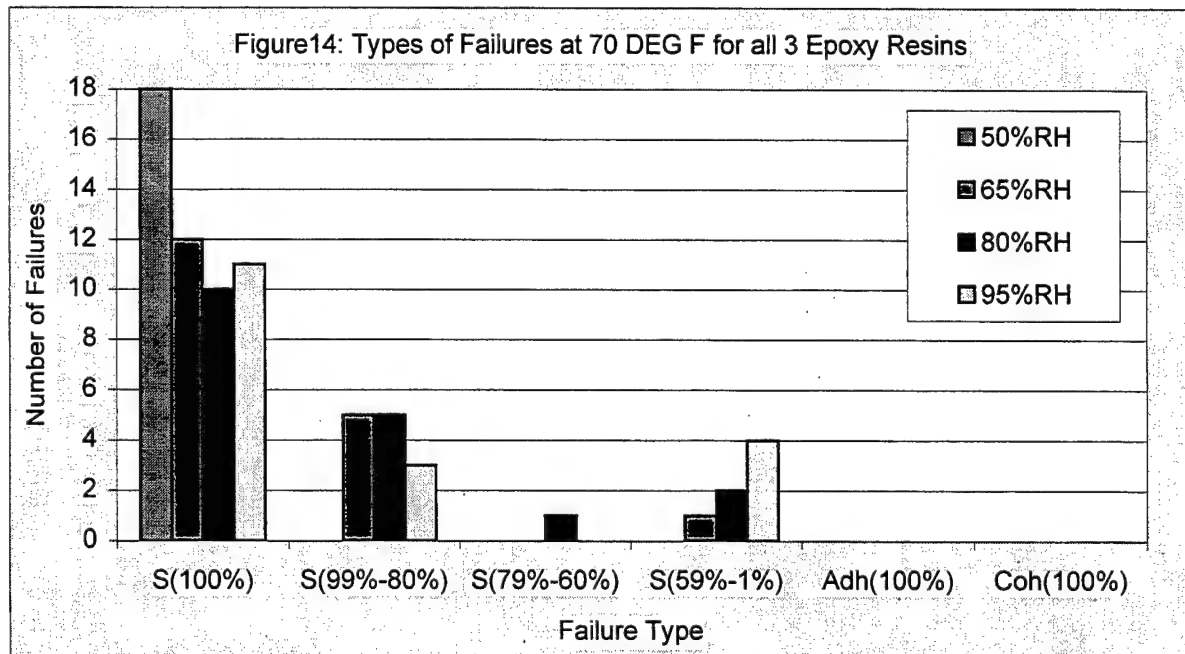
Figure 13: Madewell 1312 at 100°F

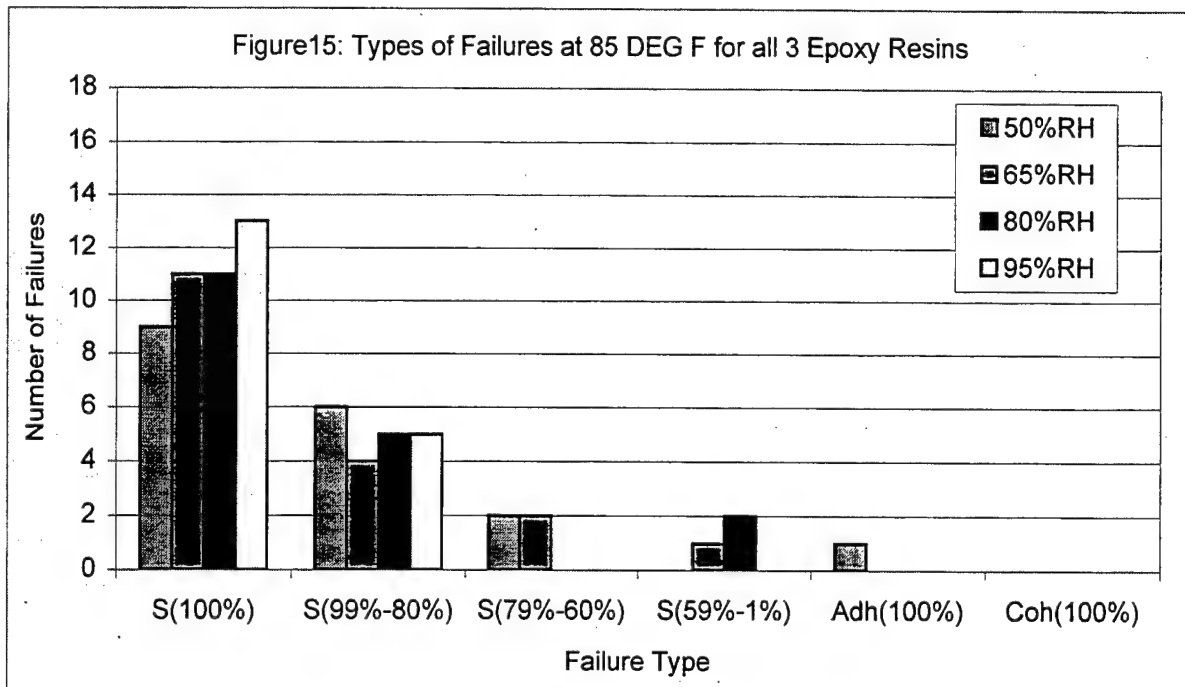Figure 14: Failure Types at 70°F
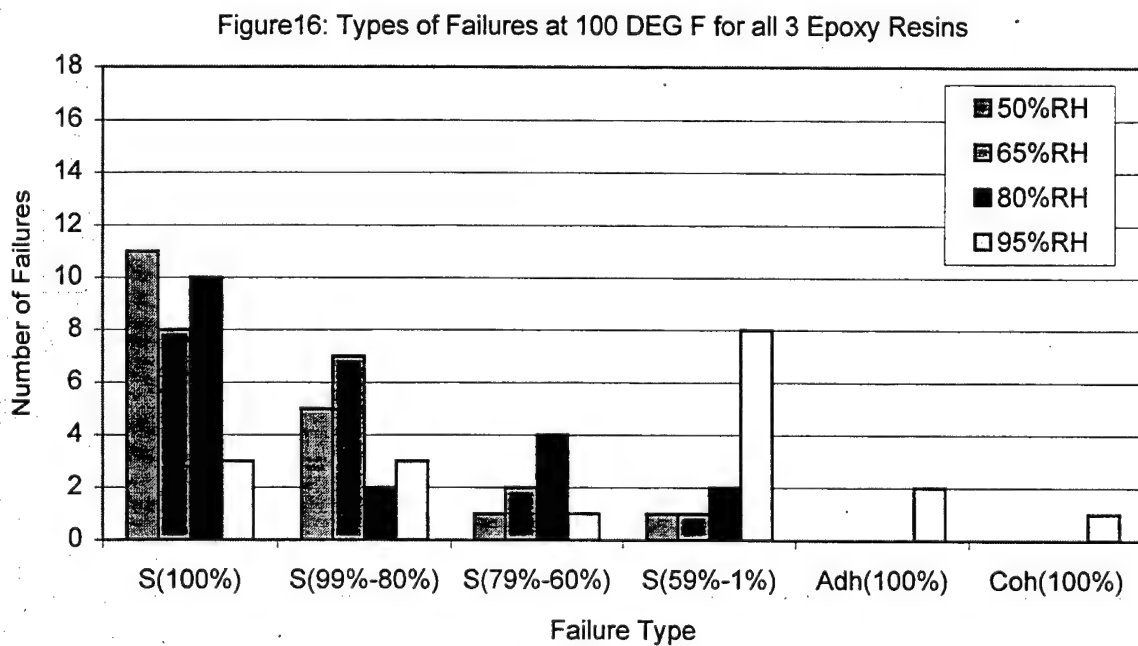
Figure 15: Failure Types at 85°F

Figure 16: Failure Types at 100°F

APPENDIX A

This appendix includes data for the various adhesives and primers used. Data were obtained and summarized from the manufacturer's specifications.

Table A1. Properties of Sikadur 30

TYPICAL DATA FOR SIKADUR 30 *(Material and curing conditions @ 73F and 50% R.H.)* *Sikadur 30 is a 2-component, 100% solids, moisture-tolerant structural epoxy paste adhesive*	
SHELF LIFE	2 years in original, unopened containers.
STORAGE CONDITIONS	Store dry at 40-95F. Condition material to 65-85F before using.
COLOR	Light gray.
MIXING RATIO	Component 'A': Component 'B' = 3:1 by volume.
CONSISTENCY	Non-sag paste.
POT LIFE	Approximately 70 minutes @ 73F. (1 qt.)

TENSILE PROPERTIES (ASTM D-638)

7 day	Tensile Strength	3,600 psi (24.8 MPa)
	Elongation at Break	1%
	Modulus of Elasticity	6.5×10^5 psi

FLEXURAL PROPERTIES (ASTM D-790)

14 day	Flexural Strength (Modulus of Rupture)	6,800 psi (46.8 MPa)
	Tangent Modulus of Elasticity In Bending	1.7×10^6 psi

SHEAR STRENGTH (ASTM D-790)   14 day   Shear Strength   3,600 psi (24.8 MPa)

BOND STRENGTH (ASTM C-882): Hardened Concrete to Hardened Concrete

2 day	(moist cure)	Bond Strength	2,700 psi (18.6 MPa)
2 day	(dry cure)	Bond Strength	3,200 psi (22.0 MPa)
14 day	(moist cure)	Bond Strength	3,100 psi (21.3 MPa)

Hardened Concrete to Steel

2 day	(moist cure)	Bond Strength	2,600 psi (17.9 MPa)
2 day	(moist cure)	Bond Strength	3,000 psi (20.6 MPa)
14 day	(moist cure)	Bond Strength	2,600 psi (17.9 MPa)

DEFLECTION TEMPERATURE (ASTM D-648)

7 day   Deflection Temperature (fiber stress loading = 264 psi)   118F (47C)

WATER ABSORPTION (ASTM D-570)

24 hours Total Water Absorption   0.03%

COMPRESSIVE PROPERTIES (ASTM D-695)

Compressive Strength, psi	40F	73F	90F
4 hour	-		5,500 (37.9 MPa)
8 hour	-	3,500 (24.1 MPa)	6,700 (46.2 MPa)
16 hour	-	6,700 (46.2 MPa)	7,400 (51.0 MPa)
1 day	750 (5.1 MPa)	7.800 (53.7 MPa)	7,800 (53.7 MPa)
3 day	6,800 (46.8 MPa)	8,300 (57.2 MPa)	8,300 (57.2 MPa)
7 day	8,000 (55.1 MPa)	8,600 (59.3 MPa)	8,600 (59.3 MPa)
14 day	8,500 (58.6 MPa)	8,600 (59.3 MPa)	8,900 (61.3 MPa)
28 day	8,500 (58.6 MPa)	8,600 (59.3 MPa)	9,000 (62.0 MPa)

MODULUS OF ELASTICITY, PSI   7 day 3.9×10^5 psi

Table A2. Properties of Sikadur 32 Hi-Mod

TYPICAL DATA FOR SIKADUR 32 HI-MOD
(Material and curing conditions @ 73F and 50% R.H.)
Sikadur 32 is a 2-component, 100% solids, moisture-tolerant structural epoxy paste adhesive

SHELF LIFE	2 years in original, unopened containers.
STORAGE CONDITIONS	Store dry at 40-95F. Condition material to 65-75F before using.
COLOR	Concrete gray.
MIXING RATIO	Component 'A': Component 'B' = 1:1 by volume.
VISCOSITY	Approximately 2,800 cps.
POT LIFE	Approximately 30 minutes. (60 gram mass)

CONTACT TIME

40F	73F	90F
14-16 hr	3.5-4 hr	1.5-2 hr

COMPRESSIVE MODULUS, PSI: 7 day 2.0×10^5 psi (1379.3 MPa)

TENSILE PROPERTIES (ASTM D-638)

7 day	Tensile Strength	5,100 psi (35.1 MPa)
	Elongation at Break	1.8%
14 day	Modulus of Elasticity	3.2×10^5 psi (2206.9 MPa)

FLEXURAL PROPERTIES (ASTM D-790)

14 day	Flexural Strength	
	(Modulus of Rupture)	7,400 psi (51 MPa)
	Tangent Modulus of Elasticity	
	In Bending	4.7×10^5 psi

SHEAR STRENGTH (ASTM D-790) 14 day Shear Strength 5,900 psi (40.6 MPa)

WATER ABSORPTION (ASTM D-570) 24 hours Total Water Absorption 0.79%

DEFLECTION TEMPERATURE (ASTM D-648)

7 day	Deflection Temperature	121F
	(fiber stress loading = 264 psi)	

BOND STRENGTH (ASTM C-882): Hardened Concrete to Hardened Concrete

2 day	(moist cure)	Plastic Concrete to Hardened Concrete	1,700 psi
14 day	(moist cure)	Plastic Concrete to Hardened Concrete	2,400 psi
		Plastic Concrete to Steel	1,900 psi

COMPRESSIVE PROPERTIES (ASTM D-695)

Compressive Strength, psi	**40F**	**73F**	**90F**
8 hour	-	-	100 (.18 MPa)
16 hour	-	2,400 (16.5 MPa)	4,500 (31 MPa)
1 day	-	4,600 (31.7 MPa)	6,400 (44.1 MPa)
3 day	800 (5.5 MPa)	8,100 (55.8 MPa)	8,200 (56.5 MPa)
7 day	8,100 (55.9 MPa)	10,300 (71 MPa)	8,200 (56.5 MPa)
14 day	8,100 (55.9 MPa)	10,300 (71 MPa)	8,200 (56.5 MPa)
28 day	8,800 (60.7 MPa)	10,300 (10,300 MPa)	8,200 (56.5 MPa)

Table A3. Properties of Sikadur 55 SLV

TYPICAL DATA FOR SIKADUR 55 SLV			
(Material and curing conditions @ 73F (23C) and 50% R.H.)			
Sikadur 55 is a 2-component, 100% solids, moisture-tolerant epoxy crack healer/penetrating sealer. It is a super low viscosity hi-strength adhesive formulated specifically for grouting dry and damp cracks.			

SHELF LIFE	2 years in original, unopened containers.
STORAGE CONDITIONS	Store dry at 40-95F (4-35C). Condition material to 65-75F before using.
COLOR	Clear, amber
MIXING RATIO	Component 'A': Component 'B' = 2:5:1 by volume.
VISCOSITY	Approximately 95 cps
POT LIFE	Approximately 25 minutes

TACK FREE TIME

	-40F	60F	73F
	-	16 hours	6 hours

TENSILE PROPERTIES (ASTM D-638)

		40F	60F	73F
7 day	Tensile Strength	-	5,000psi (34.4 MPa)	7,500psi (51.7 MPa)
	Elongation at Break	-	1.6%	2.3%

BOND STRENGTH (ASTM C-882)

Hardened Concrete to Hardened Concrete
2 day	(moist cure)	1,400 psi (9.6 MPa)
14 day	(moist cure)	2,700 psi (18.6 MPa)

Hardened Concrete to Steel
2 day	(moist cure)	1,800 psi (12.4 MPa)
14 day	(moist cure)	2,000 psi (13.8 MPa)

FLEXURAL PROPERTIES (ASTM D-790)

7 day	Flexural Strength	9,500 psi (65.5 MPa)
	Tangent Modulus of Elasticity	4.8×10^5 psi

SHEAR STRENGTH (ASTM D-790) 14 day Shear Strength 7,600 psi (52.4 MPa)

DEFLECTION TEMPERATURE (ASTM D-648) 7 day 120F (49C)

WATER ABSORPTION (ASTM D-570)

7 day Total Water Absorption (24 hour Immersion) 0.61%

COMPRESSIVE PROPERTIES (ASTM D-695)

Compressive Strength, psi	40F	73F	90F
1 day	-	250 (1.7 MPa)	5,150 (35.5 MPa)
3 day	1,200 (8.2 MPa)	11,600 (80 MPa)	12,900 (88.9 MPa)
7 day	7,900 (54.4 MPa)	13,700 (94.4 MPa)	14,800 (102 MPa)
14 day	12,600 (86.8 MPa)	14,000 (96.5 MPa)	15,300 (105.5 MPa)
28 day	13,000 (89.6 MPa)	14,000 (96.5 MPa)	15,800 (108.9 MPa)

MODULUS OF ELASTICITY, PSI 7 day 3.7×10^5 psi

Table A4. Properties of Madewell 1312F

TYPICAL DATA FOR MADEWELL 1312F
Madewell 1312F is a 2-component, 100% solids, epoxy saturant (resin) specifically designed for use with glass, carbon or other synthetic fiber reinforcement systems for protection and/or reinforcement of concrete, steel, wood or composite structures.

SHELF LIFE			
STORAGE CONDITIONS			
COLOR	Transparent blue		
MIXING RATIO	Component 'A': Component 'B' = : by volume.		
VISCOSITY	Approximately cps		
POT LIFE	Approximately 45 minutes at 100F, longer at lower temperatures		

TACK FREE TIME	**40F**	**60F**	**73F**
	-		

TENSILE PROPERTIES (ASTM D-638)

	40F	**60F**	**73F**
7 day Tensile Strength	-		
Elongation at Break	-		

BOND STRENGTH (ASTM C-882)
Hardened concrete to hardened
    2 day   (moise cure)
    14 day   (moist cure)
Hardened Concrete to Steel
    2 day   (moist cure)
    14 day   (moist cure)

FLEXURAL PROPERTIES (ASTM D-790)
7 day   Flexural Strength
    Tangent Modulus of Elasticity

SHEAR STRENGTH (ASTM D-790)

DEFLECTION TEMPERATURE (ASTM D-648)   7 day

WATER ABSORPTION (ASTM D-570)
7 day   Total Water Absorption   (24 hour Immersion)

COMPRESSIVE PROPERTIES (ASTM D-695)

Compressive Strength, psi	**40F**	**73F**	**90F**
1 day	-		
3 day	-		
7 day	-		
14 day	-		
28 day	-		

MODULUS OF ELASTICITY, PSI   7 day